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LONDON:

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PREFACE.

THE contents of the following pages have been reprinted with considerable additions from THE STUDENTS' JOURNAL, in which publication they originally appeared under the title of "General Outlines of Chemistry."

The endeavour has been throughout to present the leading facts of the Science in as systematic a manner as possible, and by explaining the meaning of every symbol, no matter where or how often it may occur, to facilitate the acquirement of a subject concerning the difficulty of which there can be but one opinion. Should this object have been attained, in however small a degree, it will be a matter of no small gratification to the

AUTHOR.

8, TORRINGTON SQUARE, W.C.
May, 1877.

ERRATA.

Page 6—7th line from the bottom, for 1° read 1.

„ 8—7th line from the top, for unstsble read unstable.

„ 10—5th line from the bottom, for idodide read iodide.

„ 11—4th line from the bottom, for Ntrogen read Nitrogen.

„ 18—1st line on page, for nitroxl read nitroxyl.

„ 20—3rd line from the bottom, for H_3SO_4 read H_2SO_4.

„ 21—8th line from the top, for substance read substances.

„ 43—19th line from the top, for Phosphorus with Hydrogen read Phosphorus with Oxygen.

„ 48—2nd line from the top, for H_3AsO_4 read H_3AsO_3.

„ 48—8th line from the top, for odourless read colourless.

„ 48—7th line from the bottom, for deep read pale.

AIDS TO CHEMISTRY.

OXYGEN.

Symbol, O. Combining weight, 16. Density, 16.

Description.—A gas; colourless, inodorous, invisible, and tasteless. Slightly soluble in water. The great supporter of combustion, and most magnetic of gases. Specific gravity is 1·1056, the specific gravity of air being 1. A dyad element, replacing two monads as in the case of water $\left.\begin{matrix}H\\H\end{matrix}\right\}O$. Necessary to decay, germination, and putrefaction.

Sources.—Exists free in the atmosphere, of which it constitutes one-fifth by bulk, and combining with almost all organic bodies and most minerals, forms nearly half by weight of the solid earth. Fluorine is remarkable for forming no compounds with this gas. Eight-ninths by weight of water consist of oxygen.

Preparation.—(1.) By heating red mercuric oxide (HgO).

$$HgO + heat = Hg + O.$$

Metallic mercury remains at the bottom of the vessel, and oxygen is given off, and is collected over water.

(2) By heating chlorate of potash ($KClO_3$).

$$KClO_3 + heat = KCl + 3O.$$

Chloride of potassium and oxygen are formed.

(3) By heating manganese dioxide, otherwise called black oxide of manganese (MnO_2).

$$3MnO_2 + heat = MnO, Mn_2O_3 + 2O.$$

The black oxide is decomposed into the red mangano-manganic oxide and oxygen.

(4) By mixing a small quantity of black oxide of manganese with the chlorate of potash, it is found that the oxygen is given

off at a much lower temperature from the chlorate, thus facilitating the evolution of the gas, while the manganese dioxide does not undergo the slightest change.

(5) By electrolysis from water (H_2O), the oxygen separating at the platinode or positive pole.

(6) By the addition of strong sulphuric acid (H_2SO_4) to manganese dioxide.

$$2MnO_2 + 2H_2SO_4 = 2MnSO_4 + 2H_2O + 2O.$$

Sulphate of manganese, water, and oxygen are formed.

(7) Oxygen is set free by the action of sunlight upon the carbonic acid (CO_2) contained in the air, through the chlorophyll, or green colouring matter of plants. The plant takes up the carbon (C) for its growth, the oxygen being set free for the support of the respiration of animals.

Tests.—(1) A glowing chip of wood plunged into the gas immediately *bursts into flame.*

(2) Sulphur which burns with a pale blue flame in air, emits a *bright violet light* in oxygen.

(3) Phosphorus inflamed and placed in this gas exhibits *dazzling brilliancy.*

(4) By tipping a bundle of fine iron wire, or a steel watch-spring with burning sulphur or glowing amadou (a spongy substance), and placing it in a jar of oxygen *showers of splendid scintillations* are produced, oxide of iron dropping in the molten state to the bottom of the jar.

OZONE—O_2O.

Description.—An allotropic modification of oxygen; may be termed *condensed* oxygen, since it is found that this substance is one and a-half times as heavy as O, *i.e.*, three volumes of O condense to form two volumes of ozone. It is a gas of a peculiar odour which is perceptible during the working of an electrical machine; possesses great bleaching and disinfecting properties, and is completely soluble in oil of turpentine.

Preparation.—(1) By passing a series of electric sparks through the air or through oxygen.

(2) By allowing a stick of phosphorus to hang in a bottle filled with *moist* air.

(3) By the electrolytic decomposition of water, in which small quantities of ozone are produced.

(4) By the action of strong sulphuric acid (H_2SO_4) upon permanganate of potash ($KMnO_4$) thus—

$$2KMnO_4 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + 2O + O_2O.$$

Sulphate of potash, sulphate of manganese, water, oxygen, and ozone are produced.

Tests.—(1.) Sets iodine (I) free from iodide of potassium (KI), hence paper impregnated with starch and iodide of potassium is turned blue by ozone.

$$6KI + 3H_2O + O_2O = 6I + 6KHO.$$

Iodide of potassium, water and ozone give free iodine and liquor potassæ.

(2). Converts protosalts of manganese into persalts, and sulphite of lead into sulphate.

HYDROGEN.

Symbol, H. Combining weight, 1. Density, 1.

Description.—A gas; colourless, invisible, tasteless, and inodorous. The lightest body known, being 14·47 times lighter than air. Very slightly soluble in water. The specific gravity, air being taken as the unit, is 0·0693.

A monad element, and the standard of atomic weights.

Sources.—Chiefly found in combination; with oxygen in water of which it forms one-ninth by weight, and in nearly all organic bodies.

Preparation.—(1.) From water (H_2O) by metallic sodium (Na). Thus—

$$Na + H_2O = NaHO + H.$$

(2.) From steam over red-hot iron (Fe) in a gun barrel. Thus—

$$4H_2O + 3Fe = Fe_3O_4 + 8H.$$

Ferrous-ferric oxide (Fe_3O_4) remains.

(3.) From sulphuric acid (H_2SO_4) diluted and zinc (Zn). Thus—

$$H_2SO_4 + Zn = ZnSO_4 + 2H.$$

sulphate of zinc remaining.

(4.) By electrolysis of water, hydrogen separating at the negative pole or zincode.

Test.—Hydrogen is not a supporter of combustion, but a combustible body. This can be shown by placing a lighted taper in a jar of the gas; the flame of the taper is *extinguished*, but another flame is observed at the mouth of the jar; this is of a very pale blue colour, possesses little luminosity, but intense heat, and is produced by the *combustion* of the hydrogen, the result being a few drops of water.

Hydrogen with oxygen forms two compounds.

(1) Hydrogen monoxide, or, water. H_2O.

(2) Hydrogen dioxide, H_2O_2.

(1) HYDROGEN MONOXIDE (H_2O) WATER.

It is found that when hydrogen burns in air, water is formed by the union of the gas with oxygen. In 1781, Cavendish showed that two volumes of hydrogen unite with one volume of oxygen to form water. He made a mixture in this proportion in a jar, and then passed the gases into a strong vessel furnished with a stop-cock from which the air had been pumped out. An electric spark was passed through two platinum wires melted through the glass; an explosion followed, dew was seen to be deposited upon the sides of the vessel, and upon opening the stop-cock under water, this liquid rushed in and completely filled the whole space originally occupied by the mixed gases. The glass was weighed before and after the explosion, and the weight of the gases being known, the weight of the water produced was the same as that of the gases which combined.

The composition of water is determined in two ways:—

(1) By SYNTHESIS.

(2) By ANALYSIS.

SYNTHESIS, or the placing together of the ingredients, is performed in the following manner:—A long, accurately graduated, glass tube, called a *eudiometer* is taken. This is open at one end and closed at the other, and through the top of the closed end are melted two platinum wires. The tube is filled with mercury, and then inverted, open end downwards, over a trough filled with the same metal. Hydrogen is admitted into the tube, and the volume measured (say 100 volumes); oxygen is then allowed to enter (say 75 volumes), and the volume of the two mixed gases measured. An electric spark is now passed through the gases by means of the platinum wires; a flame passes down through the gas, showing that combination has occurred, and the water produced is deposited as dew upon the inside of the tube; this will only occupy about $\frac{1}{2000}$ part of the bulk of the constituent gases, so its volume may be neglected. Upon opening the bottom of the eudiometer, the mercury in the tube rises, and we find that only 25 volumes of gas remain, which turns out to be pure oxygen. Thus, 100 volumes of hydrogen require exactly 50 volumes of oxygen for their complete combustion. By a modification of this experiment, it can be shown that the volume of gaseous water occupies exactly 100 volumes; or, two volumes of H unite with one of O to form two volumes of steam, hence density of steam or weight of one volume is

$$\frac{16 + 2}{2} = 9$$

Analysis, or the splitting up into the constituents, is performed as follows:—A glass vessel is filled with water, acidulated with sulphuric acid (H_2SO_4), to assist the conduction of electricity; two test tubes, also filled with water, are then inverted into this vessel over two small platinum plates attached to wires passing through a caoutchouc stopper at the bottom of the glass. On connecting the plates with the terminals of a galvanic battery, an evolution of gas from each is observed: that disengaged from the plate in connection with the *platinum end* of the battery is found to be *pure oxygen*; while that from the plate in connection with the *zinc end* is *pure hydrogen*. If the tubes be graduated, the volume of the hydrogen is found to be very little more than double that of the oxygen, for since O is rather more soluble than H, we do not get quite the exact proportions. Oxygen being sixteen times as heavy as hydrogen, and these gases combining to form water in the proportions by volume of one of the former to two of the latter, we now know that the proportions by weight in which these gases exist in water must be as sixteen to two.

Free O and H combine together, when a light is applied, with such force that a dangerous explosion occurs from the sudden expansion caused by the great heat evolved. If a soda-water bottle be filled one-third full of O, and two-thirds with H, and a flame applied to the mouth, the gases combine with a sudden detonation like the report of a pistol. The *oxyhydrogen blowpipe* is employed to develop the great heat evolved by the combination of the two gases. These are contained separately in two caoutchouc bags, and are only brought together at the point where combination is desired, thus avoiding the danger of explosion. The flame thus produced is only slightly luminous, but is so intensely hot, that the most difficultly fusible metals, such as platinum, are *easily melted* in it; whilst iron-wire burns in the flame with *beautiful scintillations*. A piece of chalk or lime placed in the flame becomes heated to *bright* whiteness, and emits *intense light*.

In nature we find water in three forms:—

(1) Solid as ice.
(2) Liquid as water.
(3) Gaseous as steam or vapour.

At all temperatures between 0° and 100° C, water assumes the liquid form; above 100° it entirely takes the gaseous (under the ordinary atmospheric pressure of 760 mm.) The melting point of ice, being a constant temperature, is taken as the zero of the centigrade scale; water may under certain conditions be cooled below 0° C without solidifying; still, ice can never exist at a temperature above 0° C. In its passage from the solid to the liquid state water becomes reduced in volume, and on freezing, a sudden expansion (from one volume to 1·099) takes place. Observe the splitting of rocks during the winter. The water which has penetrated their cracks and crevices freezes and widens these openings, and by frequent repetition of the process the rock at last is split into pieces. Hollow balls of cast iron may easily be split in two by filling them with water, closing by a tight-fitting screw, and exposing them to a temperature below 0° C.

In passing from the solid to the liquid state, a given weight of water takes up or *renders latent* just as much heat as would suffice to raise the temperature of the same weight of water through 79° C; the *latent heat of water* is therefore said to be seventy-nine thermal units—a thermal unit implying the *amount of heat required to raise a unit weight of water through* 1° C. When water freezes, the *heat of liquidity* becomes *sensible.* A similar disappearance of heat occurs with all substances on passing from the solid to the liquid form. If we take a hot saturated solution of Glauber's salts (sodium sulphate) and allow it to cool, while it remains undisturbed it retains the liquid form, but if agitated, it at once begins to crystallise, and soon becomes a solid mass. If a delicate thermometer be plunged into the salt while solidifying, a sudden rise of temperature will be noticed.

Water *heated* from 0° C to 4° C contracts, thus forming a remarkable exception to the general law, that bodies expand with heating and contract on cooling; on *cooling* from 4° to 0°, it expands again; above 4°, it follows the ordinary law. Thus we say that the *point of maximum density of water is* 4° C; *i.e.*, a given bulk of water will weigh more at this temperature than at any other. The amount of contraction on heating is but small (one volume of water at 4° becoming 1° + 0·00012 at 0°), yet its influence upon nature is most important. Were it not for this our climate would be arctic. In the freezing of large lakes and rivers, the cold winds gradually cool the surface-water which, becoming heavier, sinks, and lighter and warmer water rises to its place. This process goes on until the temperature of the whole mass is reduced to 4°, and then the surface water no longer sinks, since it is always lighter than the deeper water at 4°. Ice is formed only at the top, the mass of water retaining a temperature of 4°. If water became heavier as it cooled down to the freezing point, a continual circulation would be kept up until the mass was cooled to 0°, when solidification of the whole would take place. Sea-water rarely, if ever, freezes *en masse*, on account of the great depth of water which prevents the whole being cooled down to freezing point.

When water is heated to 100° C, it boils, or enters into ebullition, *i.e.*, steam is disengaged from the most heated surface. During this process, a large quantity of heat becomes latent, and the *latent heat of steam is said to be* 536 *thermal units.* When water passes into the gaseous state or evaporates, heat is absorbed, and so much heat may be thus abstracted from water, that we may cause it to freeze by its own evaporation. Water possesses the power of rising in vapour at all temperatures, and this power is called the *elastic force*, or *tension*, of aqueous vapour. Again, *water boils when the tension of its vapour is equal to the superincumbent atmospheric pressure.* On tops of mountains water boils at a temperature below 100° C, because the atmospheric pressure is less than at the sea level.

To obtain *pure* water, we are obliged to *distil* river or spring water; that is, we boil the water and collect the fluid formed by the condensation of the steam produced. Thus the solid matters are left behind. Rain water is the purest form of water in nature, but even this may contain impurities. Sea-water contains about thirty-five parts of solid matter (twenty-eight parts consisting of sodium chloride or common salt) in solution, in 1,000 parts of water. Most salts are more or less soluble in water, and crystallise upon the evaporation of the fluid. The solubility of salts is generally greater in hot water than in cold.

Water of crystallisation, is the water which is necessary for the preservation of the crystalline form of certain salts, and, upon the driving off of which by heat, the crystals fall to powder. The amount of this water varies in different cases:—

Thus, we have

Sulphate of iron $FeSO_4 + 7H_2O$
Sulphate of magnesia $MgSO_4 + 7H_2O$
Sulphate of zinc $ZnSO_4 + 7H_2O$

Whilst—

Sulphate of copper is $CuSO_4 + 5H_2O$

And—

Sulphate of manganese $MnSO_4 + 5H_2O$.

If a saline compound absorb water from the atmosphere, it is termed *deliquescent*, as acetate of potash ($KC_2H_3O_2$); if under the same circumstances it loses water, it is called *efflorescent*, as in the case of phosphate of soda ($Na_2HPO_4 + 12H_2O$).

(2.) HYDROGEN DIOXIDE (H_2O_2). *Hydroxyl.*

Description and properties.—A liquid of syrupy consistence and very unstable; does not occur in nature. Possesses powerful oxidising properties, bleaches a solution of litmus, and has a somewhat metallic taste. It has of late years been used as a test for bloodstains, since with freshly-prepared tincture of guaiacum and blood it strikes a blue colour.

Preparation.—(1.) From barium dioxide (BaO_2) and hydrochloric acid (HCl).

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2$$

Barium chloride and hydrogen dioxide are formed.

(2.) By passing carbonic acid gas (CO_2) through barium dioxide (BaO_2) suspended in water.

$$BaO_2 + H_2O + CO_2 = BaCO_3 + H_2O_2.$$

Barium carbonate separates out as a white powder, insoluble in water, and H_2O_2 remains in solution; upon bringing this substance into contact with ozone, common oxygen and water are produced. If silver oxide be brought in contact with H_2O_2 metallic silver is produced, together with water and common oxygen.

NITROGEN.

Symbol, N. Combining weight, 14. Density, 14.

Description.—A gas; properties, negative. viz.: colourless, tasteless, inodorous, neither supporting combustion; nor combustible; not poisonous; animals placed in nitrogen die from oxygen starvation, hence the name *azote*, by which it is sometimes designated. Slightly lighter than air. Specific gravity, 0·972, air being 1·0. A triad element replacing three monads, as in the case of ammonia, $N\begin{cases}H\\H\\H\end{cases}$ Does not readily combine with other bodies.

Sources.—Exists free in the atmosphere, of which it constitutes four-fifths by bulk; occurs in combination in the bodies of animals, in many plants, and in chemical compounds, as nitre (nitrate of potash KNO_3), whence its name (nitre generator). Also in some mineral waters.

Preparation.—(1) By burning phosphorus (P) in a bell-jar filled with air, the mouth of which is placed in a vessel full of water; white fumes at first fill the jar, consisting of phosphorus pentoxide (P_2O_5), and as these subside and dissolve in the water beneath, the nitrogen is left nearly pure.

(2) By passing air over red-hot metallic copper (Cu); cupric oxide (CuO) is formed, and nitrogen is set free.

(3) By passing chlorine (Cl) through *excess* of ammonia (NH_3). Thus—

$$6Cl + 2NH_3 = 6HCl + 2N.$$

Hydrochloric acid remains in solution, and nitrogen is given off. If the chlorine be in excess, a most explosive oily compound is formed, called chloride of nitrogen (NCl_3?)

(4) By heating the nitrite of ammonium (NH_4NO_2). Thus—

$$NH_4NO_2 + \text{heat} = 2H_2O + 2N.$$

COMPOUNDS OF NITROGEN WITH HYDROGEN.

AMMONIA.

Symbol, NH_3. Molecular weight, 17. Density, 8·5.

Description.—The only (separable) compound of N with H. A gas; colourless, irrespirable, with odour of "hartshorn"; lighter than air, specific gravity 0·59 (air = 1). The volatile alkali; very soluble in H_2O, and capable of being liquefied.

Sources and Preparation.—Is produced in decay, and in combustion, where bodies contain N and H, and to some extent in respiration. Chiefly obtained from the decomposition of animal and vegetable matters containing nitrogen and hydrogen, either at the ordinary temperature or by the influence of heat. By heating horns, clipping of hides, or coal, ammonia is given off, hence known (in the first mode) as *spirits of hartshorn.* A compound called Sal-ammoniac (NH_4Cl), or chloride of ammonium, was first prepared by the Arabs by heating camels' dung in the Deserts of Libya, near the Temple of Jupiter Ammon (whence the name ammonia). The dried excrement of sea-birds (guano) and the urine of animals contain considerable quantities of NH_3.

The great source of ammonia and its compounds at the present time is the ammoniacal liquor of the gas-works. The mode of preparation is the following:—

(a) Hydrochloric acid (HCl) is added to the ammoniacal liquor, forming chloride of ammonium (NH_3HCl).

(b) Slaked lime is added (CaH_2O_2). Thus—

$$2NH_3HCl + Ca\,H_2O_2 = CaCl_2 + 2H_2O + 2NH_3.$$

Ammonia may also be prepared by the action of nitric acid (HNO_3) upon metallic zinc (Zn). Thus—

$$9HNO_3 + 4Zn = 4(Zn\ 2NO_3) + 3H_2O + NH_3.$$

The gas may be collected by displacement, the neck of the receiver being turned downwards, or it may be collected over mercury, but not over water on account of its extreme solubility.

Tests.—(1) Possesses a strong *alkaline* reaction.

(2) Its solution turns red vegetable colours *blue*.

(3) Gives *white fumes* when placed near any mineral acid, such as nitric (HNO_3), hydrochloric (HCl), or sulphuric (H_2SO_4). The most striking reactions are the

(4) *Deep sapphire blue* colour, produced when an *excess* of liquor ammoniæ is added to a solution of a salt of *copper*, and

(5) The *white* precipitate of hydrargyrum ammoniatum (NH_2HgCl) when liquor ammoniæ is added to corrosive sublimate ($HgCl_2$).

COMPOUNDS OF NITROGEN WITH OXYGEN.

Five in number, viz :—

(1) *Nitrogen monoxide, nitrous oxide, or laughing gas,* N_2O.
(2) *Nitrogen dioxide, or nitric oxide* NO or N_2O_2.
(3) *Nitrogen trioxide, or nitrous anhydride,* N_2O_3.
(4) *Nitrogen tetroxide, or hyponitric acid,* NO_2 or N_2O_4.
(5) *Nitrogen pentoxide, or nitric anhydride,* N_2O_5.

Here we have a striking instance of the *law of chemical combination in multiple proportion.*

In these compounds the O is in the proportion of the numbers 1, 2, 3, 4, 5 to one and the same quantity of N. While 28 parts by weight of N, combined with 16 of O, form 44 parts of nitrogen monoxide, we see that any other compounds of those elements contain some simple multiple of 16 parts by weight of O, either 2 × 16, 3 × 16, 4 × 16, or 5 × 16, and that no compounds exist containing any *intermediate quantity* of O.

N and O do not *readily* combine together, but may be made to do so under certain circumstances. Suppose a series of electric sparks to be passed through a vessel full of dry air, *red coloured vapours* having a *peculiar acrid smell* are soon noticed; these consist of *tri- and tetr-oxides of nitrogen.* They have the power, like ozone, of liberating iodine from potassium idodide, and can thus be made to colour starch *blue.*

NITROGEN MONOXIDE, NITROUS OXIDE.

Symbol, N_2O. Molecular weight, 44. Density, 22.

Description.—A gas; colourless, inodorous, with a slightly sweetish taste. Respirable for a time, capable of liquefaction, and somewhat soluble in water. Supports combustion nearly as well as oxygen. Specific gravity (air being 1) is 1·527.

Preparation.—(1) By heating ammonium nitrate (NH_4NO_3). Thus—

$$NH_4NO_3 + \text{heat} = 2H_2O + N_2O.$$

(2) By the action of metallic zinc (Zn) upon dilute nitric acid (HNO_3). Thus—

$$10HNO_3 + 4Zn + H_2O = 4Zn\,2NO_3 + 6H_2O + N_2O.$$

Nitrate of zinc, water, and nitrous oxide are formed. This gas is best collected over *warm* water.

Tests.—(1) A glowing chip of wood plunged into nitrous oxide is *rekindled*, burning with a brighter flame than in air.

(2) Phosphorus burns in this gas with nearly as bright a light as in oxygen.

(3) The *feeble* flame of sulphur is extinguished, but when *burning strongly* yields a *bright light.*

(4) When *inhaled* a peculiar *exhilarating effect* is produced, hence the name "laughing gas."

NITROGEN DIOXIDE. NITRIC OXIDE.

Symbol, N_2O_2 or NO. Molecular weight, 30. Density, 15.

Description and Tests.—A gas; colourless, and irrespirable; has never been condensed to a liquid; does not easily support combustion (ignited phosphorus, unless burning brightly, being extinguished on being placed in nitric oxide). In contact with oxygen it immediately forms red fumes, consisting of the higher oxides of nitrogen. Specific gravity (air being 1) is 1·038.

Preparation.—(1) By the action of nitric acid (HNO_3) upon copper turnings (Cu). Thus—

$$3Cu + 8HNO_3 = 3(Cu2NO_3) + 4H_2O + N_2O_2.$$

Nitrate of copper, water, and nitric oxide are formed.

(2) By nitric acid upon metallic mercury (Hg). Thus—

$$3Hg + 8HNO_3 = 3(Hg2NO_3) + 4H_2O + N_2O_2.$$

Nitrate of mercury, water, and nitric oxide are formed.

NITROGEN TRIOXIDE. NITROUS ANHYDRIDE.

Symbol, N_2O_3. Molecular weight, 76. Density, 38.

Description and Tests.—A gas, of *an orange red colour* at ordinary temperatures, but at − 18° C a *blue* volatile liquid, emitting a red and irritating vapour. With water it forms *nitrous acid* (HNO_2). Thus—

$$N_2O_3 + H_2O = H_2N_2O_4 \text{ or } 2HNO_2.$$

(HNO_2 is a very unstable substance, decomposing, when the water is warmed, into nitric acid and nitric oxide. Thus—

$$3HNO_2 = H_2O + N_2O_2 + HNO_3).$$

Nitrous acid gives riseto salts calltd *nitrites*. Thus, with ammonia, we have (NH_4NO_2) *nitrite of ammonia.*

Preparation.—(1) By mixing 4 volumes of dry N_2O_2 with 1 volume of O, and cooling the mixture to − 18° C. Thus—

$$N_2O_2 + O = N_2O_3.$$

(2) By the action of nitric acid (HNO_3) and H_2O upon arsenious anhydride (As_2O_3). Thus—

$$As_2O_3 + 2HNO_3 + 2H_2O = 2H_3AsO_4 + N_2O_3.$$

Arsenic acid and nitrogen trioxide are formed.

NITROGEN TETROXIDE. HYPONITRIC ACID.

Symbol, N_2O_4 or NO_2. Molecular weight, 46. Density, 23.

Description and Tests.—A gas; of an *orange red* colour; liquid under pressure; has a suffocating odour; poisonous (if breathed in only small quantity producing inflammation of the lungs); solidifies at − 9° C in long prisms. The chief resultant in air from decomposed nitric acid.

Preparation.—By heating the nitrate of lead ($Pb2NO_3$). Thus—

$$Pb2NO_3 + \text{heat} = PbO + O + N_2O_4.$$

Oxide of lead, oxygen, and nitrogen tetroxide are formed. (By water N_2O_4 is decomposed into nitric acid (HNO_3) and nitric oxide (N_2O_2). Thus—

$$3N_2O_4 + 2H_2O = 4HNO_3 + N_2O_2).$$

NITROGEN PENTOXIDE. NITRIC ANHYDRIDE.

Symbol, N_2O_5. Molecular weight, 54. Density, 27.

Description and Preparation.—A white crystalline substance; in brilliant right rhombic prisms. Prepared by passing dry chlorine gas (Cl) over nitrate of silver ($AgNO_3$). Thus—

1st Stage.—$AgNO_3 + 2Cl = AgCl + O + NO_2Cl.$

Chloride of silver, oxygen, and a yellow liquid called nitroxyl chloride are formed.

2nd Stage.—$AgNO_3 + NO_2Cl = AgCl + N_2O_5.$

Nitrate of silver and nitroxl chloride form chloride of silver and nitrogen pentoxide. This substance (N_2O_5) very easily decomposes, and unites with great energy with H_2O. Thus—

$$N_2O_5 + H_2O = H_2N_2O_6 \text{ or } 2HNO_3; \text{ forming}$$

NITRIC ACID.

Symbol, HNO_3. Molecular weight, 63.

Description.—A fuming, corrosive, colourless liquid, with strongly acrid odour, and intensely acid taste. Entirely volatized by heat. Specific gravity 1·517, A monobasic acid.

Sources.—Both kingdoms of nature; generally with potash, soda, lime, and magnesia, as nitrates. These are found in various parts of the world on the surface of the earth, and in some mineral waters, and are frequent constituents of vegetable juices.

Preparation.—(1) By the action of sulphuric acid (H_2SO_4) upon sodium nitrate ($NaNO_3$). Thus—

$$NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3.$$

Sodium-hydrogen sulphate remains in the retort, and nitric acid distils over into a receiver.

(2) By the action of sulphuric acid upon potassium nitrate (KNO_3). Thus—

$$KNO_3 + H_2SO_4 = KHSO_4 + HNO_3.$$

Potassium-hydrogen sulphate remains behind.

Tests.—For the *concentrated* acid (HNO_3.)

(1) Stains the skin *yellow*, forming *picric* or *carbazotic acid.*

(2) Turns morphia and brucia *red.*

(3) In the presence of hydrochloric acid dissolves *gold leaf.*

(4) Gives off ruddy brown fumes with metals, as copper, mercury, silver, &c.

(5) Gives *white* fumes with the vapour of ammonia.

(6) Bleaches a solution of indigo.

For the *dilute* acid, or a *nitrate.*

Upon the addition of a *green* crystal of sulphate of iron with a drop or two of strong sulphuric acid, the crystal is turned to a red brown colour.

Nitric acid forms salts called nitrates. They are all soluble in H_2O, and deflagrate upon charcoal.

Action on the metals.—Gold, platinum, ferrum(iron) and aluminum are unattacked by HNO_3. Tin (stannum Sn) is oxidised to meta-stannic acid ($H_2Sn_5O_{11} + 4H_2O$). Antimony (stibium

Sb) to antimonic acid ($HSbO_3$), both insoluble in H_2O. Copper (Cu) is converted into soluble cupric nitrate ($Cu2NO_3$). Mercury (Hg) into mercurous nitrate ($HgNO_3$) and mercuric nitrate ($Hg2NO_3$). Silver (Ag) into argentum nitrate ($AgNO_3$). Zinc (Zn) into zinc nitrate ($Zn2NO_3$).

THE ATMOSPHERE

Is the gaseous envelope of the earth, and forms the ocean of air at the bottom of which we live. The average composition of air may be said to be the following:—

100 volumes of air contain—

Oxygen	20·6	volumes.
Nitrogen	77·9	„
Carbonic acid	0·04	„
Aqueous vapour (about)	1·46	„
Ammonia	traces.	
	100·00	

Since the last three ingredients are present in small and variable proportion, they are generally separated first in an analysis of air.

Of *carbonic acid*, there are present from 4 to 6 volumes in 10,000 of air. The proportion of ozone is various, but is greater in the country than in town. To detect the carbonic acid, we expose a vessel containing lime-water to the open air. The lime-water soon becomes turbid, from the formation of insoluble carbonate of lime.

The amount of aqueous vapour is dependent for the most part upon temperature, and varies with latitude, season, and region, &c.

The quantity of ammonia in the form of carbonate and nitrate is small, being about 1 part in 1,000,000 of air: its presence can only be shown by acting upon large quantities of air.

Oxygen may be proved to exist in the air, by combustible bodies being converted into oxides when made to burn in it. Thus, by burning hydrogen (H) we have water (H_2O) formed.

The existence of nitrogen is demonstrated by the result of combustion in confined portions of air, as has been shown previously in the section on preparing this gas.

The pressure of the atmosphere is observed when we remove the air from beneath the hand by an air pump; we then find that the hand is pressed down with a force equal to nearly

15lbs. on every square inch. From this it is evident that the human body must consequently support *several tons*, but under ordinary circumstances this pressure is not perceptible, since it is exerted *equally* in every direction.

To measure the pressure of the air we make use of

THE BAROMETER.

This consists in the simplest form of a *straight glass tube*, about 800 millimetres (33 inches) in length, open at one end, and closed at the other. It is filled with mercury, and placed open end downwards in a vessel containing the same metal. The mercury then sinks in the tube to a point about 760 millimetres (32 inches) from the surface of the mercury in the vessel. In this position it is sustained by the force exerted by the air. As this pressure increases, the height of the mercurial column becomes greater; as it diminishes, so does the column fall. In order to compare the bulk of two gases, they must always be compared under like conditions of pressure and temperature; it is, therefore, agreed to compare all the volumes of gases at the *standard pressure of* 760 *millimetres of mercury, and at the standard temperature of* 0° C. It is difficult to say where the air exactly ceases, but it seems that the limit is about 45 miles from the level of the sea. Of course, the atmosphere, having weight and elasticity, its lower layers must be more compressed than those above them; but if the whole atmosphere were throughout of the same density, it would only reach to a height a little more than 5 miles above the sea level.

As to the *chemical composition of the atmosphere*, it must be borne in mind that the air is *not a chemical compound*, but a *mechanical mixture* of its constituents. This conclusion is arrived at on the following grounds:—

(1) If O and N are brought together in the proportions in which they are found in air, *no elevation of temperature, and no alteration in bulk* takes place (as is the case when gases combine chemically), and still the mixture acts exactly like air.

(2) The relative quantities of the two gases are *not those of their combining weights, nor of any simple multiples of these weights.*

(3) Although in general the proportions of the two gases are constant, instances not unfrequently occur in which *this ratio differs* from the ordinary one.

(4) When air is shaken up with water, some of it is dissolved, but can be easily expelled by boiling; upon analysis this ex-

pelled air is found to consist of oxygen and nitrogen in the relative proportions of 1 to 1·87. It would have been quite impossible to decompose the air by simply shaking it up with water if it had been a chemical compound; *the compound would have dissolved as a whole*, and upon analysis, the air expelled by boiling would have consisted of oxygen and nitrogen as 1 to 4, the proportions of the original air.

The air is therefore only a mixture, since a larger amount of O is dissolved than corresponds to that contained in the atmosphere, a fact due to the greater solubility in water of oxygen over nitrogen.

The best method of determining the amounts by volume of O and N contained in the air is by the *eudiometer* (*eudia*, clear weather; *metron*, a measure; a measure of the clearness or purity of the air, viz., what quantity of oxygen it contains). The same arrangement is used as in the eudiometric synthesis of water. Into the tube, previously filled with mercury, air is introduced in sufficient quantity to fill it about one-sixth full. We can accurately ascertain the volume of this air by reading off the number of millimetre divisions on the tube to which the mercury reaches.

A quantity of pure hydrogen, more than sufficient to combine with all the oxygen present is now added, and the volume of this gas determined. An electric spark is now passed through the mixture, and after the explosion *the volume* is determined as before. This is found to be less than before explosion, water having been formed by the union of the whole of the oxygen with part of the hydrogen. We already know that 2 volumes of H unite with exactly 1 volume of O to form H_2O (water); then one-third of the diminution in volume represents the O that has disappeared, and therefore the volume of O contained in the air taken. Now suppose the volume of air amounted to 100 volumes, and after the addition of the hydrogen the volume of the mixture was 150 volumes. After explosion we find 87 volumes remain, therefore 63 volumes have disappeared. Then the volume of O contained in 100 volumes of air is

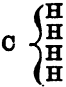
$$\frac{63}{3} = 21$$

The most careful analyses of air collected in various parts of the globe have shown that the relative quantities of O and N remain the same, or nearly the same, from whatever region obtained. Whether from the depths of mines, from 20,000 feet above the surface of the earth, from the Arctic seas, or from the tropics, the air contains from 20·9 to 21 volumes of oxygen per cent.

The composition of air by volume, and the relative densities of the constituent gases ($N = 14$; $O = 16$) being known, its composition by weight can be calculated. Thus, in 100 grams of air, we find that 76·84 grams of N are mixed with 23·16 grams of O, and the mean of a large number of experiments shows that 100 parts by weight of air contain 77 parts by weight of N and 23 of O.

CARBON.

Symbol, C. Combining weight, 12.

Description.—A solid element. A tetrad replacing 4 atoms of monad hydrogen as shown in the composition of marsh gas  $C\begin{cases}H\\H\\H\\H\end{cases}$ and existing in 3 "allotropic" modifications, viz.:—

(1) The diamond.
(2) Graphite, plumbago, or, black lead.
(3) Charcoal, lamp-black, or, amorphous carbon.

THE DIAMOND.

The purest form of carbon, and the hardest gem known; can be entirely converted into carbonic dioxide (CO_2) by combustion in O. By intense heat, in absence of air, it is reduced to a coke-like substance. The specific gravity varies from 3·3 to 3·5. It crystallizes in cubes and octahedra, and is insoluble in all media, and infusible. Is largely used for glass-cutting, and is cut into various forms by its own dust. The mode in which the diamond has been formed is utterly unknown.

GRAPHITE, OR, PLUMBAGO.

A black metallic-looking substance, hence the name black-lead; leaving a greasy stain when drawn upon paper. Crystallizes in 6-sided plates, bearing no relation to the form of the diamond. Sp. gr. 2·18 to 2·38. Is much used for the manufacture of pencils.

CHARCOAL, OR, AMORPHOUS CARBON.

Is the light-giving principle of flame. The purest form of charcoal-carbon is lamp-black. It also occurs as wood charcoal, coal, coke, and animal charcoal. Much lighter than the other forms. Sp. gr. varying from 1·6 to 2·0. A piece of charcoal floats upon water in consequence of its porosity, but if finely powdered it instantly sinks. It is a great absorbent of gases and colouring matters, and is used as a disinfectant in hospitals, &c. *Carbo ligni*, *wood charcoal*, is obtained from wood charred by exposure to a red heat, without access of air.

COMPOUNDS OF CARBON WITH OXYGEN.

two in number, viz:—

(1) Carbon monoxide, or carbonic oxide, CO.
(2) Carbon dioxide, or carbonic anhydride, CO_2.

CARBON MONOXIDE.

Symbol, CO. Molecular weight, 28. Density, 14.

Description.—A gas, not occurring naturally, but artificially produced. Colourless, with slightly oppressive odour; has never been liquefied. Very poisonous. Does not support combustion, but *burns with a light blue flame*, forming carbonic anhydride (CO_2). Sp. gr. (air = 1) is 0·969. Very slightly soluble in H_2O.

Preparation.—(1) By passing carbonic anhydride (CO_2) over red-hot charcoal (C). Thus—

$$CO_2 + C = 2CO.$$

(2) By heating oxalic acid ($H_2C_2O_4$) with sulphuric acid (H_2SO_4). Thus—

$$H_2C_2O_4 + H_2SO_4 = H_2SO_4, H_2O + CO_2 + CO.$$

The sulphuric acid abstracts the elements of water (H_2O); the carbonic anhydride and carbon monoxide are evolved as gases, and are collected in a long cylindrical tube; upon shaking up lime water (CaH_2O_2) in the tube, carbonate of lime ($CaCO_3$) is formed, and carbon monoxide left.

(3) By heating zinc (Zn) and chalk ($CaCO_3$) to redness in a gun-barrel. Thus—

$$Zn + CaCO_3 = Zn\,O + CaO + CO,$$

oxide of zinc, lime, and carbon monoxide are formed.

(4) By heating carbonic anhydride (CO_2) and hydrogen. Thus—

$$CO_2 + 2H = H_2O + CO.$$

(5) By heating ferrocyanide of potassium ($K_4FeC_6N_6, 3H_2O$) with sulphuric acid (H_2SO_4) and water (H_2O). Thus—

$$K_4FeC_6N_6, 3H_2O + 3H_2O + 6H_2SO_4 = 2K_2SO_4 + FeSO_4 + 3(NH_4)_2\,SO_4 + 6CO,$$

Sulphate of potash, sulphate of iron, sulphate of ammonia, and carbon monoxide are formed.

(2) CARBON DIOXIDE, CARBONIC ANHYDRIDE.

Symbol, CO_2 Molecular weight, 44. Density, 22.

Description.—A gas; colourless, inodorous, with a slightly acid taste. Tolerably soluble in water; neither combustible nor supporting combustion. Liquid under pressure, and solid by spontaneous evaporation, forming snow-white flakes. Constitutes the "choke damp" and "after damp" of mines; specific gravity 1·529.

Sources.—Occurs free in the air, and in the waters of many mineral springs. Is evolved from the craters of active volcanoes. Is given off in the processes of fermentation, respiration, combustion, decay, putrefaction, and germination. When a room contains 0·10 per cent. of CO_2 it is unfit for continued respiration. Combined with lime and magnesia, carbon dioxide occurs plentifully in nature.

Its salts are called carbonates, and are mostly insoluble.

Preparation.—(1) By heating calcium carbonate ($CaCO_3$) to redness. Thus—

$$CaCO_3 + \text{red heat} = CaO + CO_2.$$

(2) By the action of a mineral acid, as hydrochloric acid (HCl) upon $CaCO_3$. Thus—

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2,$$

Chloride of calcium, water and carbonic anhydride are formed.

(3) Charcoal burns in oxygen to CO_2.

Carbonic anhydride (CO_2) + H_2O = Carbonic acid (H_2CO_3.)

COMPOUNDS OF CARBON WITH HYDROGEN.

These are very numerous, and exist in gaseous, liquid, and solid forms. For the present we shall only deal with three of the simplest, leaving the remainder for consideration under Organic Chemistry.

(1) Methyl Hydride, Methylene, Light Carburetted Hydrogen, or Marsh Gas, CH_4.

(2) Acetylene C_2H_2.

(3) Ethylene, Heavy Carburetted hydrogen, or Olefiant Gas, C_2H_4.

METHYL HYDRIDE, MARSH GAS.

Symbol, CH_4. Molecular weight, 16. Density, 8.

Description and Sources.—A gas; colourless, inodorous, and tasteless; never liquefied. Known as "*Firedamp*" in coal mines. Produced in *stagnant pools* by the decomposition of dead leaves (hence its name, marsh-gas). A constituent of coal gas, and evolved in volcanic districts.

Preparation.—It cannot be prepared by direct union of its elements, but is produced in the following modes:—

(1) From acetate of sodium ($NaC_2H_3O_2$) when heated with caustic soda ($NaHO$). Thus—

$$NaC_2H_3O_2 + NaHO = Na_2CO_3 + CH_4,$$

Carbonate of soda and marsh gas are formed,

(2) By passing a mixture of carbon disulphide vapour (CS_2) and sulphuretted hydrogen (H_2S) over red-hot copper (Cu). Thus—

$$8Cu + CS_2 + 2H_2S = 4Cu_2S + CH_4.$$

Cuprous sulphide and marsh gas result.

This gas burns with *a blueish-yellow non-luminous flame*, forming carbon dioxide and water. When mixed with 10 *times its volume of air, or twice its volume of* O, it explodes suddenly and violently upon ignition.

ACETYLENE.

Symbol, C_2H_2.

Is formed by the direct union of carbon and hydrogen, at a very high temperature. It is a colourless gas, burning with a bright luminous flame, and having a peculiar disagreeable odour which may be noticed when a candle burns with a smoky flame. It combines with certain metals, as copper and silver, and these compounds very easily decompose with explosion. C_2H_2 unites directly with hydrogen to form

ETHYLENE.

Symbol, C_2H_4. Combining weight, 28. Density, 14.

Description and Sources.—A gas; colourless, with a sweetish taste; has been condensed by high pressure and a temperature of $-110°$ to a colourless liquid. It is an important constituent of coal gas, and burns with a *smoky luminous* flame, forming carbon dioxide and water. Detonates powerfully when mixed *with three times its bulk* of O and fired. It is called olefiant gas because it combines directly with its own volume of chlorine gas (Cl) to form an oily liquid $C_2H_4Cl_2$ (Chloride of Ethylene.)

Preparation.—(1) by the destructive distillation of coal. (2) By heating alcohol (C_2H_6O) with sulphuric acid (H_2SO_4.) Thus—

$$C_2H_6O + H_3SO_4 = H_2SO_4, H_2O + C_2H_4.$$

The sulphuric acid abstracts the elements of water and C_2H_4 is evolved as a gas.

COAL GAS.

In order to prepare this gas, the coal is heated in a closed retort.

The results of this heating are—

(1) Volatile bodies formed and expelled.
(2) A residue of impure carbon left as *coke*.

The volatile products are tar, ammonia, water, and gas. The tar yields substance from which the *aniline colours* are produced.

The ammonia is the chief source of the *ammoniacal salts.*

The gas consists of (1) *luminous* and (2) *non-luminous hydrocarbons.*

The *luminous* gases are olefiant gas (C_2H_4) and other hydrocarbons having an analogous composition, as C_3H_6 and C_4H_8, C_5H_{10}, &c.

The *non-luminous* gases are hydrogen (H,) carbonic Oxide (CO) and marsh gas (CH_4.)

The *impurities* are carbon dioxide (CO_2), sulphuretted hydrogen (H_2S), and the vapour of carbon disulphide (CS_2).

THE STRUCTURE OF FLAME.

Flame is gas highly ignited. The hottest flames do not necessarily give off much light. Luminosity depends upon the presence of solid matter which becomes heated to whiteness. In a burning candle the flame presents three separate parts.

(1) The *dark* central zone of unburnt gas around the wick;
(2) The *luminous* zone of incomplete combustion;
(3) The *non-luminous* zone of complete combustion.

The blow-pipe flame can be divided into two parts:

(1) The *Oxidizing* or *outer* flame with excess of oxygen, and
(2) The *Reducing* or *inner* flame with excess of carbon.

THE DAVY LAMP.

A certain temperature is required to inflame every mixture of gases; until this temperature is attained the mixture will not take fire. A flame may be cooled sufficiently to put it out by placing a coil of cold copper wire over it, but if the coil be previously heated, the flame continues to burn. If a piece of wire gauze containing about 700 meshes to the square inch be held close over a jet of gas, and the gas lighted we may remove the gauze several inches above the jet, and the inflammable gas does not take fire *below*, the flame burning only *above* the gauze. The heat is so quickly conducted away by the wires that the temperature of the gas at the lower side of the gauze is not raised sufficiently high to produce ignition.

Upon this principle Sir Humphry Davy constructed his safety lamp. Thus—

An oil lamp is enclosed in a wire gauze covering; air can pass through the meshes of the gauze, and the products of combustion of the oil can escape, but still no flame can proceed from the inside to the outside of the gauze; if the lamp be placed in a most inflammable mixture of air and firedamp, immediate ignition *externally* is not possible, although the mixture takes fire and burns *inside* the gauze. Of course, after a time, when the gauze becomes over heated, the surrounding firedamp may attain the temperature requisite for its ignition.

CARBON WITH NITROGEN.

Forms only one compound, viz.:

CYANOGEN.

Symbol, CN (sometimes Cy). Molecular weight, 26.

Description.—A gas; colourless, poisonous, with an odour of peach blossoms. Specific gravity 1·806. Does not support combustion, but *burns with a rose-coloured flame*, forming carbon dioxide and free nitrogen. Combines with metals to form cyanides. Belongs to a class of bodies called *compound radicals*, and is monobasic, replacing one atom of monad hydrogen, as shown in the composition of prussic acid, H/CN. Has been condensed to a colourless liquid.

Preparation.—By heating a metallic cyanide, such as cyanide of mercury (HgC_2N_2 or $HgCy_2$), metallic mercury and a black substance (paracyanogen) are left, and cyanogen gas is given off. It is best collected over mercury, since water dissolves 4 times its bulk of the gas.

Carbon and nitrogen do not unite together, but by passing N over a white-hot mixture of charcoal (C) and carbonate of potash (K_2CO_3) we obtain cyanide of potassium (KCN). Thus—

$$K_2CO_3 + 2N + 4C = 3CO + 2KCN.$$

From this KCN can be prepared a number of bodies, all containing CN, and possessing peculiar properties. The name cyanogen is given to this group on account of its forming with iron some blue compounds (*kuanos*, blue, and *gennao*, I produce).

A compound of cyanogen with iron and potassium called *Ferrocyanide of Potassium* ($K_4Fe\,Cy_6$, $3H_2O$) or *Yellow* Prussiate of Potash is prepared by heating together horns and hoofs and clippings of hides in an iron pot with carbonate of potash. By passing chlorine gas through K_4FeCy_6, $3H_2O$ we obtain

Ferricyanide of Potassium (K_3FeCy_6) or *Red* Prussiate of Potash. Thus—

$$K_4FeCy_6, 3H_2O + Cl = KCl + 3H_2O + K_3FeCy_6.$$

This latter salt gives no special precipitate with *persalts* of iron, but yields a *dark blue precipitate* with the *protosalts* of that metal.

THE COMPOUND OF CYANOGEN WITH HYDROGEN IS HYDROCYANIC OR PRUSSIC ACID.

Symbol, HCN or HCy. Molecular weight, 27.

Description.—In the anhydrous or undiluted state this substance is a colourless, limpid, volatile liquid. Specific gravity 0.7058 at 5°C, boiling at 26°. Feebly acid, with odour of peach blossoms or bitter-almond oil. Dreadfully poisonous, inhalation even in small quantities producing giddiness and headache. It occurs in small quantities in some kernels and leaves of the orders Amygdaleæ and Pomeæ.

Preparation.—(1) By acting upon cyanide of potassium (KCN) with dilute sulphuric acid (H_2SO_4). Thus—

$$2KCN + H_2SO_4 + H_2O = K_2SO_4 + H_2O + 2HCN,$$

Sulphate of potash, water, and prussic acid are formed.

(2) By passing sulphuretted hydrogen gas (H_2S) over dry mercuric cyanide (HgC_2N_2). Thus—

$$HgC_2N_2 + H_2S = HgS + 2HCN,$$

Mercuric sulphide and prussic acid result.

(3) By the addition of sulphuric acid (H_2SO_4) to Ferrocyanide of Potasium ($K_4FeCy_6, 3H_2O$). Thus—

$$2K_4FeCy_6, 3H_2O + 3H_2SO_4 = K_2Fe_2Cy_6 + 3K_2SO_4 + 6H_2O + 6HCy,$$

Everitt's yellow salt, sulphate of potash, water and prussic acid are formed.

Tests.—

(1) Its odour and volatility.

(2) The formation of the *white cyanide of silver* upon the addition of a solution of nitrate of silver ($AgNO_3$). Thus—

$$AgNO_3 + HCy = HNO_3 + AgCy,$$

Nitric acid and cyanide of silver are formed.

This cyanide of silver has the following characters:—

(*a*) It is soluble in *boiling strong nitric acid.*

(*b*) When heated it gives off *cyanogen gas* which, upon the application of a light, burns with a *rose-coloured* flame.

(3) The formation of ***Prussian blue*** $\left\{Fe_4(FeCy_6)_3 + 18H_2O\right\}$ by the following method:—

Liquor Potassæ (KHO) is added to the prussic acid (HCy) forming cyanide of potassium (KCy); then a proto-and per-salt of iron are added; this is followed by the formation of a proto-and per-cyanide of iron; but Prussian blue *cannot exist* in the presence of the alkali *potash*, so a mineral acid (sulphuric acid is the best) is employed to neutralize the alkali. Upon the addition of the acid, the Prussian blue is immediately developed. Thus—

$$\left\{\begin{array}{c}\text{Prussic acid}\\ 18H\,Cy\end{array}\right. + \left\{\begin{array}{c}\text{Liq. potassæ}\\ 18KHO\end{array}\right. + \left\{\begin{array}{c}\text{Ferrous sulphate}\\ 5Fe\,SO_4\end{array}\right.$$

$$+ \left\{\begin{array}{c}\text{Ferric Sulphate}\\ Fe_2\,(SO_4)_3\end{array}\right. + \left\{\begin{array}{c}\text{Sulphuric acid}\\ H_2SO_4\end{array}\right. = \left\{\begin{array}{c}\text{Sulphate of potash}\\ 9K_2SO_4\end{array}\right.$$

$$+ \left\{\begin{array}{c}\text{Hydrogen}\\ 2H\end{array}\right. + \left\{\begin{array}{c}\text{Ferrocyanide of Ferric iron or Prussian blue}\\ Fe_4\,(FeCy_6)_3,\ 18H_2O.\end{array}\right.$$

(4) The formation of the *blood-red sulpho-cyanide of iron* ($Fe_2(CSy)_6$) as follows:—

Some prussic acid is heated upon a watch-glass to a syrupy consistence with a drop or two of sulphide of ammonium (NH_4HS). Thus—

(a) $HCy + NH_4HS = 2H + NH_4CSy$:

Hydrogen and sulphocyanide of ammonium (white) result.

(b) Perchloride of iron (Fe_2Cl_6) is added to NH_4CSy. Thus—

$$6NH_4CSy + Fe_2Cl_6 = 6NH_4Cl + Fe\,(CSy)_6.$$

Chloride of ammonium and sulpho-cyanide of iron (red) are formed.

The *Acidum Hydrocyanicum Dilution* of the British Pharmacopœia consists of hydrocyanic acid dissolved in water and constituting 2 per cent. by weight of the solution.

Scheele's prussic acid contains 4 per cent. of anhydrous acid.

The anhydrous acid is very volatile and speedily decomposes into a carbonaceous mass. The dilute acid can be much longer preserved if a trace of a mineral acid be present.

THE HALOGENS.

Under this heading we describe four elements, vix:—*Chlorine*, *Bromine*, *Iodine*, and *Fluorine*. They have received this name from the fact of their forming salts *analogous in their composition* to common salt, or chloride of sodium (NaCl).

CHLORINE.

Symbol, Cl. Atomic weight, 35·5. Density, 35·5.

Description and Sources.—A gas; never native; of a *greenish yellow colour* with a peculiar *disagreeable odour*, which in small quantities resembles that of seaweed; in large quantities a powerful irritant, causing inflammation of the mucous membrane, and even producing a fatal result when inhaled. Can be condensed to a heavy yellow liquid, but has never been solidified. Found combined with metals as chloride. *Dry* chlorine *will not bleach*, but *when water is added does so powerfully*. Only bleaches *vegetable colours*, mineral colours being unaffected. Is not combustible, but supports combustion. An aqueous solution of Cl will dissolve gold leaf.

Preparation.—(1) By acting upon dioxide of manganese (MnO_2) with hydrochloric acid (HCl.). Thus—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + 2Cl,$$

Manganese chloride, water, and chlorine result.

(2) By the action of sulphuric acid (H_2SO_4) upon dioxide of manganese (MnO_2) and chloride of sodium (NaCl). Thus—

$$2NaCl + MnO_2 + 2H_2SO_4 = NaSO_4 + MnSO_4 + H_2O + 2Cl.$$

sulphate of soda, sulphate of manganese, water and chlorine are formed. This gas cannot be collected over cold water or mercury, since the former dissolves 2·37 volumes of Cl at 15°, and with the latter mercuric chloride is formed. It may be collected by displacement, being nearly 2·5 as heavy as air, but is conveniently prepared over *warm* water.

Tests.—(1) Its greenish-yellow colour, and its odour.

(2) A lighted candle placed in Cl *continues to burn*, but with a very *smoky* flame; the hydrogen of the wax enters into combination with the Cl forming hydrochloric acid (HCl), whilst its carbon is given off from the wax as soot.

(3) Phosphorus burns *spontaneously* in chlorine.

(4) Certain metals, as arsenic, antimony, copper and gold, *in a fine state of division or attenuation*, take fire *spontaneously* when thrown into chlorine.

CHLORINE WITH HYDROGEN
forms
HYDROCHLORIC ACID—HYDRIC CHLORIDE.

Symbol, HCl. Combining weight, 36·5. Density, 18·25.

Description.—A gas; colourless, poisonous pungent, neither combustible nor supporting combustion. Has very acid properties and is very soluble in water, one volume of which at 15° dissolves 454 volumes of the gas.

Preparation.—(1) By the union of H and Cl in equal volumes in the sunlight or by heat. Thus—

$$H + Cl = HCl.$$

(2) By the action of sulphuric acid (H_2SO_4) upon chloride of sodium (NaCl). Thus—

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

Sodium sulphate and hydrochloric acid are formed.

Tests.—For the strong or *concentrated* acid (a solution of the gas in water).

(1) *Whitens* the skin, forming chloride of albumen.

(2) *Dissolves gold leaf* in the presence of nitric acid (HNO_3).

(3) Gives off *Chlorine gas* when added to dioxide of manganese.

(4) Gives *white fumes* with the vapour of ammonia.

For the *dilute* acid or a *soluble chloride.*

Nitrate of silver ($AgNO_3$) gives a *white* precipitate of the chloride of silver (AgCl). This precipitate is recognised by the following characters—

(*a*) It is soluble in liquor ammoniæ, and reprecipitated by nitric acid.

(*b*) It blackens by exposure to light.

(*c*) When heated, it melts to a mass called horn silver.

HCl when added to nitric acid, forms—

Aqua Regia.—This mixture dissolves the noble metals, such as gold and platinum, the solvent action being dependent upon the chlorine, which is set free by the oxidising agency of the nitric acid upon the hydrogen of the HCl, and thus soluble chlorides are formed. The nitric acid is reduced to nitrogen dioxide (N_2O_2), and nitrous oxychloride (NOCl), and nitric oxychloride ($NOCl_2$) are liberated as yellowish gases.

COMPOUNDS OF CHLORINE WITH OXYGEN.

Chlorine and oxygen do not unite directly, but indirectly they form the following compounds, viz:—

Cl_2O, chlorine monoxide, yielding $HClO$ hypochlorous acid.
Cl_2O_3, chlorine trioxide, yielding $HClO_2$ chlorous acid.
Cl_2O_4, chlorine tetroxide.
$HClO_3$, chloric acid.
$HClO_4$, perchloric acid.

No acid corresponding to chlorine tetroxide, or any oxides corresponding to chloric, and perchloric acids have as yet been prepared.

CHLORINE MONOXIDE.

Symbol, Cl_2O. Molecular weight, 87. Density, 43·5.

Description.—A gas, condensible to a red explosive liquid, very soluble in water, forming a yellow solution which bleaches vegetable colours more entirely than chlorine.

Preparation.—From mercuric oxide (HgO) and chlorine (Cl). Thus—$2HgO + 4Cl = Hg_2Cl_2O + Cl_2O$.

Mercuric oxychloride, and chlorine monoxide, are formed.

BLEACHING POWDER.

Is a mixture of chloride of calcium ($CaCl_2$), and hypochlorite of calcium ($CaCl_2O_2$). It is prepared by passing chlorine gas (Cl) into slaked lime (CaH_2O_2). Thus—

$$2CaH_2O_2 + 4Cl = 2H_2O + CaCl_2 + CaCl_2O_2.$$

The chlorine for this preparation is now obtained on a large scale by passing hydrochloric acid gas and air over heated sulphate of copper ($CuSO_4$). The H of the HCl, and the O of the air form water, setting free the chlorine. The sulphate of copper undergoes no change whatever.

HYPOCHLOROUS ACID.

Symbol, $HClO$.

A colourless liquid with a peculiar smell and strong bleaching properties.

Preparation.—From carbonate of lime ($CaCO_3$), water (H_2O), and chlorine (Cl). Thus—

$$CaCO_3 + H_2O + 4Cl = CO_2 + CaCl_2 + 2HClO.$$

Carbonic anhydride, chloride of calcium, and hypochlorous acid are formed.

CHLORINE TRIOXIDE.

Symbol, Cl_2O_3.

A gas of deep yellowish green colour. Formed by the action of nitric acid (HNO_3) upon arsenious acid (As_2O_3), chlorate of potash ($KClO_3$) and water H_2O). Thus—

$$2KClO_3 + As_2O_3 + 2HNO_3 + 2H_2O = 2H_3AsO_4 + 2KNO_3 + Cl_2O_3.$$

Arsenic acid, nitrate of potash, and chlorine trioxide result.

CHLOROUS ACID.

Symbol, $HClO_2$.

Is prepared by condensing Cl_2O_3 gas in water; it is a greenish yellow liquid, which bleaches and oxidises.

CHLORINE TETROXIDE.

Symbol, Cl_2O_4.

A deep yellow gas, and at 20°C a red liquid.

Preparation.—By the action of sulphuric acid (H_2SO_4) upon chlorate of potash ($KClO_3$). Thus—

$$6KClO_3 + 3H_2SO_4 = 3K_2SO_4 + 2HClO_4 + 2H_2O + 2Cl_2O_4,$$

Sulphate of potash, perchloric acid, water, and chlorine tetroxide result, the gas being collected by displacement.

This gas is very liable to decompose with violent explosions, and is soluble in water, yielding mixtures of chlorite and chlorate.

CHLORIC ACID.

Symbol, $HClO_3$.

A syrupy, strongly acid liquid, and a powerful oxidizing agent. When dropped upon paper it takes fire, giving up its oxygen; forms salts called chlorates, all of which are soluble in water.

Preparation.—From barium chlorate ($Ba2ClO_3$) and sulphuric acid (H_2SO_4). Thus—

$$Ba2ClO_3 + H_2SO_4 = BaSO_4 + 2HClO_3.$$

Sulphate of baryta and chloric acid result.

PERCHLORIC ACID.

Symbol, HClO. Molecular weight, 100·5.

Description.—An oil-like liquid, forming with water a crystalline hydrate. One of the most powerful oxidizing agents known; if dropped on wood or paper it instantly causes ignition, and when thrown on charcoal it decomposes with detonation. It is the most stable of all the acids derived from chlorine.

Preparation.—From chlorate of potash ($KClO_3$) and sulphuric acid (H_2SO_4). Thus—

$$4KClO_3 + 2H_2SO_4 = 2K_2SO_4 = H_2O + 3O + 2Cl + 2HClO_4.$$

Sulphate of potash, water, oxygen, chlorine and perchloric acid are formed.

The following, then, is the unbroken series of the acids of chlorine, increasing step by step by one atom of O:—

HCl, hydrochloric acid.
HClO, hypochlorous acid.
$HClO_2$, chlorous acid.
$HClO_3$, chloric acid.
$HClO_4$, perchloric acid.

COMPOUND OF CHLORINE WITH NITROGEN.

This is formed only indirectly, and its composition has not as yet been precisely ascertained. It is obtained by passing *excess* of chlorine gas through a solution of ammonia. It is an oily liquid of specific gravity, 1·653, which when touched explodes with fearful violence. Its hypothetical formula is NCl_3.

Compounds of Chlorine with Carbon.

These can only be made indirectly, and are as follows —

Carbonic chloride, CCl_4.
Ethylene chloride, C_2Cl_4.
Carbonic perchloride, C_2Cl_6.
Carbonic oxy-chloride, $COCl_2$.

With marsh gas (CH_4) the following stages in the substitution of hydrogen by chlorine occur :—

(1) $CH_4 + 2Cl = CH_3Cl + HCl$.
(2) $CH_3Cl + 2Cl = CH_2Cl_2 + HCl$.
(3) $CH_2Cl_2 + 2Cl = CHCl_3 + HCl$.
(4) $CHCl_3 + 2Cl = CCl_4 + HCl$.

The properties of these compounds must be left for discussion under organic chemistry.

BROMINE.

Symbol, Br. Combining weight, 80. Density, 80.

Description.—A fluid; the only element liquid at ordinary temperatures except mercury. Of a dark reddish-brown colour by reflected light, but hyacinth-red by light transmitted through thin layers, and emitting a vapour, irritating and poisonous. A monad replacing one atom of hydrogen, as seen in the composition of hydrobromic acid H/Br.; specific gravity at 4°C is 2·966. Freezes at −22° to a black solid, and boils at 63°. About 30 parts of water dissolve one part of Br at 15°. The solution has bleaching powers, but these are feebler than those of chlorine. Bromine is very soluble in alcohol, and more so in ether. Forms salts called bromides.

Sources.—Not free in nature. Found combined with sodium and magnesium in some mineral springs, and in sea water.

Preparation.—From " bittern," the residue of sea water, after the crystallization of common salt (NaCl). Here it exists in the form of bromide of magnesium ($MgBr_2$), and through this chlorine gas is passed. Thus—

$$MgBr_2 + 2Cl = Mg\,Cl_2 + 2Br.$$

The freed bromine is shaken up with ether, which rises with it to the surface, and is then separated by a pipette. Caustic potash (KHO) is now added, and the solution evaporated to dryness. Thus, bromide of potassium (KBr) is obtained and to this black oxide of manganese (MnO_2), and sulphuric acid, (H_2SO_4) are added. Thus—

$$2KBr + MnO_2 + 2H_2SO_4 = K_2SO_4 + MnSO_4 + 2H_2O + 2Br.$$

Sulphate of potash, sulphate of manganese, water, and bromine resulting.

HYDROBROMIC ACID.

Symbol, HBr. Molecular weight, 81. Density, 40·5.

Description.—A gas, colourless, strongly acid, fuming in moist air; very soluble in water.

Preparation.—H and Br will not unite directly, even in the sunlight, but can be made to do so:

(1) By passing them through a red-hot porcelain tube.

(2) By the action of Br and phosphorus (P) upon water. Thus—

$$P + 5Br + 4H_2O = H_3PO_4 + 5HBr.$$

Violent action takes place, and phosphoric acid and hydrobromic acid result.

COMPOUNDS OF BROMINE WITH OXYGEN.

(1) HYPOBROMOUS ACID. ($HBrO$) is known only in aqueous solution, and the corresponding monoxide (Br_2O) is altogether unknown. This acid bleaches vegetable colouring matters; and bromine forms with slaked lime an analogue to bleaching powder which consists of calcium bromide, and calcium hypobromite ($CaBr_2$, $CaBr_2O_2$).

Preparation.—By the action of bromine water upon red oxide of mercury (HgO). Thus—

$$HgO + 4Br + H_2O = HgBr_2 + 2HBrO.$$

Bromide of mercury and hypobromous acid are formed.

(2) BROMIC ACID ($HBrO_3$) corresponds to chloric acid ($HClO_3$), and forms bromates with metallic oxides, which are decomposed by heat in a similar manner to chlorates.

Preparation.—By the action of chlorine (Cl) upon bromine water ($Br + H_2O$). Thus—

$$Br + 3H_2O + 5Cl = 5HCl + HBrO_3.$$

Hydrochloric acid and bromic acid are formed.

(3) BROMINE PENTOXIDE (Br_2O) has not as yet been isolated but

(4) PERBROMIC ACID ($HBrO_4$) has been prepared by the action of bromine upon perchloric acid ($HClO_4$). Thus—

$$Br + HClO_4 = Cl + HBrO_4.$$

Chlorine and perbromic acid resulting.

BROMIDE OF NITROGEN (NBr_3) is an oily detonating fluid.

Test for Bromine.—The *orange* bromide of starch, formed by the addition of starch to this substance.

IODINE.

Symbol, I. Combining weight, 127. Density, 127.

Description.—A solid element occurring in black scales or laminar crystals, with a grey metallic lustre. Fuses at 107°C; boils at 180°C. Specific gravity. 4·95. Only slightly soluble in water, but very much so in alcohol and ether. Upon heating gives off *violet vapours*, whence its name (*ion*, a violet, and *eidos*, like). Forms salts called *iodides;* a monad element replacing one atom of hydrogen, as shown in the composition of hydriodic acid, H/I. Its properties are not so active as those of chlorine and bromine, by which it is liberated from its compounds.

Sources.—Found combined with metals in sea-water and in various springs.

Preparation.—From a solution of "kelp," the vitrified ashes of sea-wrack. After the removal of various salts (the iodine existing as iodide of sodium (NaI)), black oxide of manganese (MnO_2) and sulphuric acid (H_2SO_4) are added. Thus—

$$2NaI + MnO_2 + 2H_2SO_4 = Na_2SO_4 + MnSO_4 + 2H_2O + 2I.$$

Sulphate of soda, sulphate of manganese, water, and iodine are formed.

Tests.—(1) The *violet vapours* produced by heating free iodine.

(2) The *blue* colour which its solution forms with starch (the iodide of starch).

With regard to the preparation of the foregoing three substances, Cl, I, and Br, it will be seen that one equation will serve for them all, making, of course, the requisite substitutions. Thus—

$$2\left\{\begin{matrix}\mathrm{NaCl}\\ \mathrm{NaI}\\ \mathrm{KBr}\end{matrix}\right. + MnO_2 + 2H_2SO_4 = \left\{\begin{matrix}\mathrm{Na_2SO_4}\\ \mathrm{K_2SO_4}\end{matrix}\right. + MnSO_4 + 2H_2O + 2\left\{\begin{matrix}\mathrm{Cl.}\\ \mathrm{I.}\\ \mathrm{Br.}\end{matrix}\right.$$

IODINE WITH HYDROGEN
forms

HYDRIODIC ACID.

Symbol, HI. Molecular weight, 128. Density, 64.

Description. A gas; colourless, irritating and fuming, with strong acid reaction; very soluble in water; gradually decomposed by air. Solidifies at—55°.

Preparation.—(1) By heating iodine and hydrogen together.

(2) From tri-iodide of phosphorus (PI_3) and water (H_2O). Thus—

$$PI_3 + 3H_2O = H_3PO_3 + 3HI.$$

Phosphorous acid and hydriodic acid are formed.

IODINE WITH OXYGEN AND HYDROGEN forms the following acids:—

(1) IODIC ACID, HIO_3. Molecular weight, 176. Occurs in white crystals, and corresponds to chloric acid.

Preparation.—(1) By the oxidation of iodine by nitric acid.

(2) By the action of chlorine upon iodine water. Thus—

$$I + 3H_2O + 5Cl = 5HCl + HIO_3.$$

Hydrochloric acid and iodic acid result.

By heating HIO_3 to 170°, we obtain

Iodine pentoxide (I_2O_5), a white crystalline solid.

(2) PERIODIC ACID, HIO_4. Molecular weight, 192. A white crystalline solid, which, by heat, breaks up into I_2O_5 water and oxygen.

Preparation.—From perchloric acid ($HClO_4$) and iodine. Thus—

$$HClO_4 + I = Cl + HIO_4.$$

Chlorine and periodic acid are produced.

By heating HIO_4 to 160° we obtain *iodine heptoxide* (I_2O_7).

IODINE WITH NITROGEN.

Forms a black powder (NI_3), iodide of nitrogen. This, when touched in the dry state decomposes with a sudden loud report, or may even sometimes explode spontaneously.

Preparation.—By the action of a strong alcoholic solution of iodine upon ammonia. This may be expressed as follows:—

$$6I + 4NH_3 = 3NH_4I + NI_3.$$

Iodide of ammonium and iodide of nitrogen are formed.

FLUORINE.

Symbol, F. Combining weight, 19.

Description.—A gas?; colourless; not acting upon glass like hydrofluoric acid. A monad element replacing one atom of hydrogen, as shown in composition of hydrofluoric acid H/F. Is absorbed by caustic potash (KHO.) Thus—

$$2KHO + 2F = H_2O_2 + 2KF.$$

Forming hydrogen dioxide and fluoride of potassium.

Fluorine forms no compounds with oxygen.

Sources.—Found combined with calcium as fluorspar, (Derbyshire spar) or fluoride of calcium. Also in cryolite ($3\,NaF + AlF_3$), a double fluoride of sodium and aluminium. It has been detected in the teeth and blood of animals.

Preparation.—Has been obtained with great difficulty by passing dry iodine (I) over dry fluoride of silver (AgF). Thus —

$$AgF + I = AgI + F.$$

Iodide of silver and fluorine being formed.

FLUORINE WITH HYDROGEN

forms

HYDROFLUORIC ACID.

Symbol, HF. Molecular weight, 20. Density, 10.

Description.—A gas; colourless; very corrosive; produces painful wounds when handled; fumes strongly in the air. In contact with water it dissolves with a hissing noise, forming the hydrate ($HF, 2H_2O$).

Preparation.—From fluoride of calcium (CaF_2) by the action of sulphuric acid (H_2SO_4). Thus —

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

Sulphate of lime and hydrofluoric acid are formed. This acid has the peculiar property of *etching* glass, by uniting with the silicon of its silica (SiO_2). Thus :—

$$SiO_2 + 4HF = 2H_2O + SiF_4.$$

Water and fluoride of silicon are formed.

THE ANALOGIES, GRADATIONS, AND RELATIONS OF THE HALOGEN GROUP.

(1) Chlorine is a *gas*; bromine, a liquid; and iodine, a *solid* at ordinary temperatures.

(2) Liquid chlorine is *transparent*. Liquid bromine *slightly so*, and liquid iodine is *opaque*.

(3) The vapour of chlorine is *yellowish-green*, that of bromine is *orange*, and that of iodine is *violet*.

(4) The sp. gr. of liquid chlorine is 1·33; of liquid bromine 2·97; and of liquid iodine, 4·95.

(5) The combining weight and, therefore, the density of bromine (80) is nearly the mean of chlorine (35·5) and iodine (127). Thus —

$$\frac{35{\cdot}5 + 127}{2} = 81{\cdot}25$$

(6) They all form, with hydrogen, compounds containing equal volumes of the constituent gases united without condensation. Thus:—

H/Cl; H/Br; H/I; H/F;

(7) All these last are colourless gases which fume in air; HCl (hydrochloric acid) is *very stable*; HBr (hydrobromic acid) *not* very stable; HI (hydriodic acid) *very unstable*; HF (hydrofluoric acid) is stable.

(8) Chlorine is readily soluble in water, bromine only moderately so, and iodine is scarcely soluble.

(9) Chlorine displaces bromine and iodine from their compounds; bromine displaces iodine and fluorine; and iodine displaces fluorine.

(10) All their *crystalline forms* with metals are *cubes.*

THE METALLOIDS.

The following substances are included under this denomination, since in some respects they resemble the metals, but in others are nearly allied to many of the substances previously described.

SULPHUR.

Symbol, S. Combining weight, 32. Density, 32.

Description and Sources.—A solid element, occurring native in volcanic districts as Sicily and Iceland, crystallising in yellow rhombic octahedra; in combination, as orpiment, or arsenic trisulphide (As_2S_3), greenockite or sulphide of cadmium (CdS); Realgar As_2S_2; iron pyrites (FeS_2); magnetic pyrites (Fe_7S_8); silver-glance (Ag_2S); cinnabar or sulphide of mercury (HgS). Cobalt glance containing cobalt, arsenic and sulphur (CoAsS); nickel-glance, containing nickel, arsenic and sulphur (NiAsS); sulphide of lead or galena (PbS); zinc sulphide or blende (ZnS); copper sulphide (CuS). In combination with metals and oxygen as gypsum or calcium sulphate ($CaSO_4 + 2H_2O$); heavy spar or barium sulphate ($BaSO_4$); Glauber's salts, or sodium sulphate ($NaSO_4 + 10\ H_2O$); as sulphuretted hydrogen (H_2S), in certain springs, as those of Harrogate. Sulphur crystallises in two irreconcileable geometrical forms, and is hence called di-morphous.

Preparation.—To obtain sulphur pure, the mineral in which it is contained is heated in earthenware pots. The sulphur distils over as vapour, and is condensed in similar pots outside the furnace.

Flowers of Sulphur, is the name given to the fine crystalline powder, into which the vapour of sulphur solidifies, when it is quickly cooled below its melting point. This occurs in the same manner that aqueous vapour is deposited as snow.

Brimstone, or Roll Sulphur, is formed when sulphur is gently heated, after which it melts, and is cast into sticks.

Sulphur exists in three modifications, which are insoluble in water, and in most organic fluids, viz. :—

(1) The rhombic octahedron in nature, of specific gravity 2·07; soluble in disulphide of carbon (CS_2).

(2) The long transparent needle-shaped prismatic crystals, entirely different to the first form, also soluble in CS_2. These are produced by allowing melted sulphur to cool slowly, and have the specific gravity of 1·98. The crystals become opaque after some days' exposure to air, since they split up into crystals of the natural form.

(3) A soft tenacious caoutchouc mass of specific gravity 1·96 and insoluble in CS_2, obtained by pouring melted sulphur, heated to 230°C. into cold water; at the ordinary temperature of the air, this form of sulphur assumes the ordinary brittle variety, and if heated to 100°, it instantly changes to this form.

These modifications may be rendered apparent by simply heating sulphur: at 115°, this substance melts, and forms an amber-coloured mobile liquid. With the rise of the temperature, a dark-coloured thick treacley liquid is formed, and this at 250°, can scarcely be poured out of the vessel: above 250° a reddish-black thin liquid is formed, which remains in this condition until the temperature of 490° is attained, when it begins to boil, giving off a red vapour.

Sulphur is inflammable, and when heated in the air, burns with a blueish flame, forming a gas, sulphur dioxide (SO_2), which emits a suffocating odour.

Direct compounds of sulphur with chlorine, carbon, and most other elements are known, and many metals burn in sulphur vapour, forming sulphides.

The compounds of sulphur with oxygen and hydrogen are as follows :—

1	... ...	H_2SO_2 Hydrosulphurous acid.
2	SO_2 Sulphur dioxide yielding	H_2SO_3 Sulphurous acid.
3	SO_3 Sulphur trioxide yielding	H_2SO_4 Sulphuric acid.
4	... ...	$H_2S_2O_3$ Hyposulphurous acid.
5	... ...	$H_2S_2O_6$ Dithionic acid.
6	... ...	$H_2S_3O_6$ Trithionic acid.
7	... ...	$H_2S_4O_6$ Tetrathionic acid.
8	... ...	$H_2S_5O_6$ Pentathionic acid.

The oxides corresponding to the acids (1) (4) (5) (6) (7) (8) are unknown. The acids, sulphurous, sulphuric, and hyposulphurous, are of importance, but little is as yet known concerning the others.

HYDROSULPHUROUS ACID.

Symbol, H_2SO_2.

Description.—A yellow liquid which instantly bleaches vegetable colouring matters, and is a far more powerful reducing agent than sulphurous acid. It forms a series of salts which, although stable when dry, are in solution, rapidly converted into hyposulphites.

Preparation.—By the action of sulphurous anhydride (SO_2) and water (H_2O) upon metallic zinc (Zn). Thus—

$$Zn + 2SO_2 + H_2O = ZnSO_3 + H_2SO_2.$$

Sulphite of zinc and hydrosulphurous acid are formed.

SULPHUR DIOXIDE.

Symbol, SO_2. Molecular weight, 64. Density, 32.

Description.—A gas; pungent, colourless, irrespirable and suffocating; is always formed when sulphur is burnt, and is given off from volcanic craters.

Preparation.—(1) By acting upon metallic copper (Cu) with sulphuric acid (H_2SO_4). Thus—

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

Sulphate of copper, water and sulphur dioxide result.

(2) By the deoxidation of sulphuric acid (H_2SO_4) by means of wood charcoal (C). Thus—

$$H_2SO_4 + C = H_2O + CO + SO_2.$$

Water, carbonic oxide, and sulphur dioxide, result.

This gas may be collected over mercury, or by displacement. Cold water takes up 30 times its volume of SO_2. When cooled to -10^0 it condenses to a colourless liquid, and below -76^0 the liquid freezes to a transparent solid.

A solution of SO_2 in water consists of true sulphurous acid or hydrogen sulphite H_2SO_3. Upon boiling this liquid SO_2 escapes as a gas. Upon cooling a solution of the gas in water below 5^0 sulphurous acid separates as a crystalline hydrate (H_2SO_3 + $14H_2O$).

SO_2 is largely used for bleaching purposes, especially for substances not acted upon by chlorine, and also as an antichlor for getting rid of the excess of chlorine contained in the bleached rags from which paper is made. Thus—

$$SO_2 + 2H_2O + 2Cl = H_2SO_4 + 2HCl.$$

Sulphuric and hydrochloric acids are formed.

Tests.—(1) H_2SO_3 is a colourless liquid, with an odour of burning sulphur.

(2) It reduces gold chloride, precipitating metallic gold.

(3) It liberates iodine from its compounds, and, if starch be present, produces the blue iodide of amiden.

SO_2, when moistened with H_2O, bleaches in an exactly opposite manner to Cl, since SO_2 abstracts the oxygen and liberates the hydrogen, whilst Cl abstracts the hydrogen and liberates the oxygen.

SULPHUR TRIOXIDE. SULPHURIC ANHYDRIDE.

Symbol, SO_3. Molecular weight, 80. Density, 40.

Sulphur dioxide gas (SO_2) and oxygen (O) will not, under ordinary circumstances, unite directly to form SO_3, but if they be passed together over finely divided and heated metallic platinum, they combine to form dense white fumes which condense to long prismatic crystals of SO_3, changing after a time to white silky needles. This substance does not redden litmus, and when moulded by the fingers, does not char the skin; when in contact with water however, combination takes place with loud hissing, like a red-hot iron, sulphuric acid H_2SO_4 being formed. By gently heating the Nordhausen sulphuric acid (see below) SO_3 sublimes.

SULPHURIC ACID. HYDROGEN SULPHATE.

Symbol, H_2SO_4. Molecular weight, 98.

Description.—A heavy, oily liquid, "oil of vitriol" of specific gravity 1·848, and boiling at 338°C. It chars organic bodies, and is the most powerful acid known, except at high temperatures.

A dibasic acid, as indicated by its composition, $\left.\begin{matrix}H\\H\end{matrix}\right\}SO_4$. Most of the acids are prepared by its agency.

Preparation.—This acid was first prepared by the distillation of green vitriol or ferrous sulphate ($FeSO_4$), and in this mode is known as *fuming or Nordhausen acid*, having the formula $H_2SO_4 + SO_3$ (a mixture of sulphuric acid and sulphuric anhydride), a heavy, dark, fuming, liquid used only in the arts, chiefly for dissolving indigo.

The usual method of preparation is, however, *by the combustion of sulphur* (S) *and the oxidation of the resulting sulphurous anhydride* (SO_2) *by means of nitrous anhydride* (N_2O_3). The operation is conducted in huge leaden chambers, often of a capacity of 100,000 cubic feet, sulphur (S) or iron pyrites (FeS_2) being burnt at one end, and nitrate of potash (KNO_3) at the other. From the sulphur SO_2 is given off, while from the KNO_3 arises N_2O_3, which immediately parts with one atom of oxygen (O) to the SO_2, forming SO_3, or sulphuric anhydride; thus N_2O_2 is left, and this acquiring more O from the air, becomes again N_2O_3, ready to part with a fresh supply of O for the SO_2 continually coming off from the burning sulphur.

Jets of steam (H_2O) are now blown into the chamber, and uniting with the SO_3 form H_2SO_4. This acid falls to the floor of the chamber, and is continually drawn off, the excess of water being removed by evaporation. The chamber acid is then heated as follows:—

(1) In *leaden pans* until it attains a specific gravity of 1·72; then known as *the brown oil of vitriol of commerce* and—

(2) Concentrated in *glass* or *platinum vessels* until the maximum specific gravity and strength are acquired. We may represent the changes in the preparation as follows:—

Sulphurous anhydride		Nitrous anhydride		Nitric oxide		Sulphuric anhydride
(1) SO_2	+	N_2O_3	=	N_2O_2	+	SO_3
Sulphuric anhydride		Steam				Sulphuric acid
(2) SO_3	+	H_2O	=			H_2SO_4

Tests.—For the concentrated sulphuric acid:—

(1) Its great weight.

(2) Its energetic union with water, giving out great heat.

(3) Its charring organic bodies.

(4) With metallic Cu and heat giving off SO_2 known by its odour.

For the dilute acid or a soluble sulphate.

Any soluble salt of barium (Ba) as the chloride ($BaCl_2$) or the nitrate ($Ba2NO_3$) gives a white precipitate of sulphate of baryta ($BaSO_4$) insoluble in all alkalies and in all acids except boiling sulphuric, but from that deposited upon cooling.

Action upon the metals.

Upon the addition of water zinc, (Zn), and iron (Fe), are converted by H_2SO_4 into sulphate of zinc ($ZnSO_4$), and sulphate of iron ($FeSO_4$), with evolution of hydrogen (H); whilst copper (Cu), and mercury (Hg), become with heat and the same reagent

Sulphate of copper ($CuSO_4$), and sulphate of mercury ($HgSO_4$), with the production of sulphurous anhydride (SO_2).

HYPOSULPHUROUS ACID, HYDROGEN HYPOSULPHITE.

Symbol, $H_2S_2O_3$. Only known in metallic combination, as sodium hyposulphite ($Na_2S_2O_3 + 5H_2O$) or potassium hyposulphite ($K_2S_2O_3 + 5H_2O$). It cannot be freed from the sodium or potassium. Since these salts have the power of dissolving the silver salts which have escaped the action of light, they are largely used for fixing the image in photography. Sodium hyposulphite is prepared by passing sulphur dioxide (SO_2) into a mixture of sodium sulphide (Na_2S) and caustic soda ($NaHO$) Thus—

$$2Na_2S + 2NaHO + 4SO_2 = H_2O + 3Na_2S_2O_3$$

Water and sodium hyposulphite resulting.

DITHIONIC ACID.

Symbol, $H_2S_2O_6$; a colourless, odourless, sour liquid. All dithionates are soluble in water.

Preparation.—(a) By acting upon manganese dioxide (MnO_2) with sulphur dioxide (SO_2) Thus—

$$MnO_2 + 2SO_2 = MnS_2O_6.$$

manganese dithionate is formed.

(b) By the addition of barium hydrate (BaH_2O_2) to manganese dithionate (MnS_2O_6). Thus—

$$MnS_2O_6 + BaH_2O_2 = MnO + BaS_2O_6.$$

manganese hydrate is precipitated and barium dithionate left in solution.

(c) By acting upon barium dithionate (BaS_2O_6) with sulphuric acid (H_2SO_4). Thus—

$$BaS_2O_6 + H_2SO_4 = BaSO_4 + H_2S_2O_6.$$

Barium sulphate and dithionic acid are formed.

TRITHIONIC ACID.

Symbol, $H_2S_3O_6$. This acid decomposes spontaneously into sulphur (S), sulphurous anhydride (SO_2), and sulphurous acid (H_2SO_3).

Preparation.—From potassium hyposulphite ($K_2S_2O_3$), and sulphurous anhydride (SO_2). Thus—

$$2K_2S_2O_3 + 3SO_2 = S + 2K_2S_3O_6.$$

Sulphur and potassium trithionate are formed.

The acid is freed by hydrofluosilicic acid (H_2SiF_6). Thus—

$$K_2S_3O_6 + H_2SiF_6 = K_2SiF_6 + H_2S_3O_6.$$

Potassium fluosilicate, and trithionic acid being formed.

TETRATHIONIC ACID:

Symbol, $H_2S_4O_6$. Decomposes by heat like trithionic acid.

Preparation.—(a) By acting upon barium hyposulphite (BaS_2O_3), with iodine (I). Thus—

$$2I + 2BaS_2O_3 = BaI_2 + BaS_4O_6.$$

Iodide of barium and tethrathionate of barium result.

(b) By acting upon BaS_4O_6, with sulphuric acid (H_2SO_4). Thus—

$$BaS_4O_6 + H_2SO_4 = BaSO_4 + H_2S_4O_6.$$

Barium sulphate and tetrathionic acid are formed.

PENTATHIONIC ACID.

Symbol, $H_2S_5O_6$. Colourless, odourless, with an acid and bitter taste; a most unstable substance; gives a yellow precipitate with the subnitrate of mercury, and a yellow precipitate, (turning black) with nitrate of silver.

Preparation.—From sulphurous acid (H_2SO_3) and sulphuretted hydrogen (H_2S). Thus—

$$5H_2SO_3 + 5H_2S = 5S + 9H_2O + H_2S_5O_6.$$

Sulphur, water, and pentathionic acid result.

SULPHUR WITH HYDROGEN FORMS TWO COMPOUNDS, VIZ:—

(1) H_2S. Hydrogen sulphide, or sulphuretted hydrogen.
(2) H_2S_2. Hydrogen persulphide, or hydrogen disulphide.

SULPHURETTED HYDROGEN.

Symbol, H_2S. Molecular weight, 34. Density, 17.

Description.—A gas; colourless, narcotic, with an odour of rotten eggs; inflammable, burning with a blue flame and forming water and sulphurous anhydride.

Preparation.—(1) By passing hydrogen gas (H) through boiling sulphur (S).

(2) By the action of dilute sulphuric acid (H_2SO_4), upon sulphide of iron (FeS). Thus—

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

Sulphate of iron and sulphuretted hydrogen result.

(3) By the action of hydrochloric acid (HCl) upon sulphide of antimony (Sb_2S_3). Thus—

$$6HCl + Sb_2S_3 = 2SbCl_3 + 3H_2S.$$

Chloride of antimony and sulphuretted hydrogen result.

This gas must be collected over warm water, since in cold water it dissolves to a considerable extent, imparting its peculiar odour, and slightly acid reaction to the fluid. It can be condensed to a liquid, and frozen to a transparent ice-like solid. H_2S is produced by the putrefaction of such animal matters as albumen, and by the deoxidation of sulphates when decayed organic matters are present. Sulphuretted hydrogen is chiefly used as a reagent in the laboratory for the precipitation of metals, and by it these substances may be separated into groups. Thus—

The *Copper group.*—

The following metals are precipitated by H_2S from an *acid* solution :—

Bismuthum (Bi)	Bismuth	Black or brown.
Cuprum (Cu)	Copper	
Plumbum (Pb)	Lead	
Hydrargyrum (mercurous salt) (Hg)	Mercury	
Argentum (Ag)	Silver	
Platinum (Pt)	Platinum	Black.
Aurum (Au)	Gold	
Arsenicum (As)	Arsenic	Yellow.
Cadmium (Cd)	Cadmium	
Stannum (Sn)	Tin.	
(*a*) Stannous salts		Brown.
(*b*) Stannic salts		Yellow.
Stibium (Sb)	Antimony, orange.	

The *Iron group.*—

The following are precipitated by H_2S from an *alkaline solution*:—

Ferrum (Fe)	Iron.	
Ferrous and Ferric salts		Black.
Manganesium (Mn)	Manganese,	Flesh Colour
Cobalt (Co.)	Cobalt	Black.
Nickel (Ni)	Nickel	Black.
Chromium (Cr)	Chromium.	
(*a*) Chromous salts		Black.
(*b*) Chromic salts		Greyish-green
Uranium (U)	Uranium.	
(*a*) Uranous salts		Black.
(*b*) Uranic salts		Brownish-yellow.
Zincum (Zn)	Zinc	White.

HYDROGEN DISULPHIDE, HYDROGEN PERSULPHIDE.

Symbol, H_2S_2.

Description.—An oily liquid, closely resembling H_2O_2; possesses a peculiar smell, bleaches, and is readily decomposed into sulphur and sulphuretted hydrogen.

Preparation.—By the addition of calcium disulphide solution (CaS_2) to hydrochloric acid (HCl). Thus—

$$CaS_2 + 2HCl = CaCl_2 + H_2S_2$$

Chloride of calcium and hydrogen persulphide are formed.

SULPHUR WITH CARBON FORMS

CARBON DISULPHIDE.

Symbol, CS_2. Molecular weight, 76. Density, 38.

Description.—A liquid; volatile, colourless, and heavy, with an odour of cabbage water, possessing an acrid pungent taste, and very inflammable; insoluble in water, but soluble in ether and alcohol. The great solvent of gums, caoutchouc, sulphur, phosphorus, iodine, bromine, camphor, gutta-percha, and oils.

Preparation.—By passing the vapour of sulphur over red-hot charcoal.

Direct compounds of sulphur with carbon are known, viz.:—

$$S_2Cl_2$$
$$SCl_2$$

These are volatile liquids, and are formed by passing a current of chlorine gas over melted sulphur.

A remarkable analogy is observable (not only in their composition, but also in their chemical properties), between the sulphur compounds, and the corresponding bodies in the oxygen series. Thus we have—

H_2O Water	H_2S, sulphuretted hydrogen.
H_2O_2 Hydrogen dioxide	H_2S_2 hydrogen disulphide.
CO_2 Carbon dioxide	CS_2 Carbon disulphide.

PHOSPHORUS.

Symbol, P. Combining weight, 31. Vapour Density, 62.

Description.—Never native. Found in combination with oxygen and calcium in the bones of vertebrata, in the seeds of some plants (chiefly the cereals), and in certain minerals a triad element.

Preparation.—By the following successive processes.

(1) From powdered bone-ash which contains phosphate of lime ($Ca_3P_2O_8$)) by adding sulphuric acid (H_2SO_4). Thus—

$$Ca_3P_2O_8 + 2H_2SO_4 = 2CaSO_4 + CaH_4P_2O_8.$$

Sulphate of lime, and superphosphate of lime, resulting.

(2) By the addition of charcoal (C), to the superphosphate of lime. Thus—

$$3CaH_4P_2O_8 + 10C = Ca_3P_2O_8 + 6H_2O + 10CO + 4P.$$

Phosphate of lime, water, carbonic oxide, and phosphorus are formed. The phosphorus distils over in yellow drops, and is collected under water.

Phosphorus exists in two allotropic forms, viz.:—

(1) *A yellow wax-like solid* of specific gravity, 1·83, melting at 44°, and boiling at 290°; emits a pale phosphorescent light in the dark, giving out fumes of phosphorus trioxide P_2O_3; very inflammable and dangerous to handle. Insoluble in water, alcohol or ether, slightly soluble in oils, and very so in carbon disulphide.

(2) The *red amorphous phosphorus*, of specific gravity, 2·14; this does not take fire until heated above 260°, when it passes into the ordinary form, forming phosphorus pentoxide (P_2O_5) It is *insoluble* in carbon disulphide.

Preparation of red variety.—(1) By exposing yellow phosphorus to a temperature of 240° for some hours in an atmosphere incapable of acting upon it chemically, such as hydrogen or carbon dioxide.

(2) By heating ordinary phosphorus in a dry tube with a trace of iodine; phosphorus iodide, and red amorphous phosphorus result.

PHOSPHORUS WITH HYDROGEN FORMS TWO COMPOUNDS, VIZ.:

(1) P_2O_3. Phosphorous anhydride, or trioxide.

(2) P_2O_5. Phosphoric anhydride, or pentoxide.

PHOSPHOROUS ANHYDRIDE. PHOSPHORUS TRIOXIDE.

Symbol, P_2O_3. Molecular weight, 110.

Description.—A white non-crystalline powder; soft and readily volatile; unites with great energy with water, (H_2O) forming phosphorous acid (H_3PO_3). Thus:—

$$P_2O_3 + 3H_2O = 2H_3PO_3.$$

Preparation.—By burning phosphorus in a *limited* current of dry air.

PHOSPHORIC ANHYDRIDE. PHOSPHORIC PENTOXIDE.

Symbol, P_2O_5. Molecular weight, 142.

Description.—A white amorphous powder in soft snow-white deliquescent volatile flakes; absorbs water with great avidity, hissing like a hot iron when thrown into water, (H_2O) and forming phosphoric acid (H_3PO_4). Thus:—

$$P_2O_5 + 3H_2O = 2H_3PO_4.$$

Preparation.—By burning phosphorus in *excess* of air or oxygen.

THE COMPOUNDS OF PHOSPHORUS WITH HYDROGEN AND OXYGEN ARE FIVE IN NUMBER, VIZ:—

Metaphosphoric acid	HPO_3
Hypophosphorous acid	H_3PO_2.
Phosphorous acid	H_3PO_3
Phosphoric acid	H_3PO_4
Pyrophosphoric acid	$H_4P_2O_7$

METAPHOSPHORIC ACID.

Symbol, HPO_3.

Description.—A transparent glassy mass, known as "glacial" phosphoric acid. A monobasic acid.

Preparation.—By the addition of sulphuretted hydrogen (H_2S) to metaphosphate of silver ($AgPO_3$). Thus:—

$$2AgPO_3 + H_2S = Ag_2S + 2HPO_3.$$

Sulphide of silver and metaphosphoric acid are formed.

Upon the addition of water to this glacial acid, a solution of metaphosphoric acid is obtained, and this, upon boiling, is converted into the tribasic phosphoric acid, H_3PO_4.

Tests (1).—Nitrate of silver gives a *white* precipitate.

(2).—Albumen and acetic acid give a white precipitate.

HYPOPHOSPHOROUS ACID.

Symbol, H_3PO_2.

Description.—An acid syrupy fluid and powerful deoxydizer, precipitates gold and silver from their solutions; all the hypophosphites are soluble in water.

Preparation.—By acting upon barium hypophosphite $Ba(H_2PO_2)_2$ with sulphuric acid (H_2SO_4). Thus—

$$Ba\,(H_2PO_2)_2 + H_2SO_4 = BaSO_4 + 2H_3PO_2.$$

Sulphate of barium, and hypophosphorous acid are formed.

PHOSPHOROUS ACID.

Symbol, H_3PO_3.

Description.—Deliquescent crystals which readily decompose; throws down gold, silver, and platinum, from their solutions.

Preparation.—By acting upon the trichloride of phosphorus (PCl_3) with water (H_2O). Thus—

$$PCl_3 + 3H_2O = 3HCl + H_3PO_3.$$

Hydrochloric acid and phosphorous acid result.

PHOSPHORIC ACID. ORTHOPHOSPHORIC ACID.

Symbol, H_3PO_4.

Description.—A pleasant sour liquid, a tribasic acid.

Preparation.—(1) By acting upon the tribasic phosphate of silver (Ag_3PO_4) with sulphuretted hydrogen (H_2S). Thus—

$$2Ag_3PO_4 + 3H_2S = 3Ag_2S + 2H_3PO_4.$$

Sulphide of silver and phosphoric acid are formed.

(2) By tho action of nitric acid (HNO_3) upon phosphorus (P). Thus—

$$2P + 6HNO_3 = 2N_2O_3 + N_2O_4 + 2H_3PO_4.$$

Brown fumes of the tri-and tetr-oxides of nitrogen are given off and phosphoric acid remains. This operation must be carefully performed.

Tests.—(1) Nitrate of silver gives a *yellow* precipitate of phosphate of silver.

(2) Sulphate of magnesia, and ammonia, give a *white* precipitate of triple or ammonio-magnesian-phosphate $NH_4 MgPO_4$.

PYROPHOSPHORIC ACID.

Symbol, $H_4P_2O_7$.

Description.—Can be obtained as crystals by evaporation in vacuo.

Preparation.—(1.) By heating the tribasic phosphoric acid (H_3PO_4) to 213°. Thus:—

$$2H_3PO_4 = H_2O + H_4P_2O_7.$$

Water and pyrophosphoric acid result

(2) By acting upon pyrophosphate of silver ($Ag_4P_2O_7$) with sulphuretted hydrogen (H_2S). Thus:—

$$Ag_4P_2O_7 + 2H_2S = 2Ag_2S + H_4P_2O_7.$$

Sulphide of silver and pyrophosphoric acid result.

Test.—Nitrate of silver gives a *white* precipitate, but no precipitate is caused by albumen and acetic acid.

From the description of the foregoing substances, it will be seen that there are three distinct forms of phosphoric acid—the meta, the pyro, and the tribasic, or ortho-phosphoric. Their modes of preparation have been already described, but they may also be prepared by acting upon phosphoric anhydride (P_2O_5) by different proportions of water (H_2O) as follows:—

$$\text{Phosphoric acid}\begin{cases} P_2O_5 + H_2O = 2HPO_3 & \text{Metaphosphoric acid.} \\ P_2O_5 + 2H_2O = H_4P_2O_7 & \text{Pyrophosphoric acid.} \\ P_2O_5 + 3H_2O = 2H_3PO_4 & \text{Orthophosphoric acid.} \end{cases}$$

It may also be shown that by heating the tribasic phosphate (H_3PO_4,) and thus driving off a molecule of water, we can obtain the pyrophosphoric acid, ($H_4P_2O_7$), and by the action of heat upon this, with the loss of another molecule of water, we obtain the metaphosphoric acid, (HPO_3).

Phosphorus forms with hydrogen, three compounds, to all of which the name of phosphuretted hydrogen is applied, viz.—

$$\left.\begin{array}{l} \text{Tri-hydride of phosphorus, } PH_3 \\ \text{Di-phosphorus tetra-hydride } P_2H_4 \\ \text{Tetra-phosphorus di-hydride } P_4H_2 \end{array}\right\} \text{Phosphuretted hydrogen.}$$

PH_3 Tri-hydride of phosphorus is a gas possessing a fœtid garlic-like odour, and burning with a brilliant white flame, with the formation of water and P_2O_5.

Preparation.—1. By heating hypophosphorous acid. Thus:—

$$4H_3PO_3 + \text{heat} = 3H_3PO_4 + PH_3.$$

Tribasic phosphoric acid and trihydride of phosphorus result.

2. By the action of caustic potash (KHO) upon phosphorus (P) and water (H_2O). Thus :—

$$3KHO + 4P + 3H_2O = 3KPH_2O_2 + PH_3$$

potassium hypophosphite and trihydride of phosphorus result.

This gas is prepared under water, but as each bubble rises, it takes fire spontaneously in contact with the air, forming white rings of phosphorus pentoxide (P_2O_5) expanding as they rise. When perfectly pure, this PH_3 is not spontaneously combustible, but is usually so from the presence of the following compound.

P_2H_4. Di-phosphorus tetra-hydride is a colourless very volatile liquid of high refractive power, and spontaneously inflammable. It can be prepared by passing PH_3, through a tube cooled by a freezing mixture.

P_4H_2. Tetra-phosphorus di-hydride is a solid substance, and is prepared by passing P_2H_4, the liquid hydride into hydrochloric acid (HCl). Thus :—

$$5P_2H_4 = 6PH_3 + P_4H_2.$$

Tri-hydride of phosphorus and tetra-phosphorus di-hydride result.

P_4H_2 deposits gold and silver from their solutions, but does not affect the salts of lead.

Phosphorus with chlorine forms two compounds, viz. :—

PCl_3. Phosphorous chloride, phosphorus trichloride.
PCl_5. Phosphoric chloride, phosphorus pentachloride.

Phosphorous chloride PCl_3, is a colourless, volatile, strongly fuming liquid, and is formed by passing chlorine gas over phosphorus. It gradually decomposes into hydrochloric acid, and phosphorous acid. It may also be formed by the spontaneous combustion of phosphorus in chlorine gas.

Phosphoric chloride PCl_5, is a solid crystalline body, and decomposes by excess of water into hydrochloric acid (HCl), and tribasic phosphoric acid (H_3PO_4). It is prepared by passing excess of chlorine through the phosphorous chloride. Should water be present only in limited quantity, a liquid called *phosphoric oxy-chloride*, PCl_3O is formed. Thus :—

$$PCl_5 + H_2O = 2HCl + PCl_3O.$$

By bringing together nitrate of silver ($AgNO_3$), and PCl_3O, Thus :—

$$3AgNO_3 + PCl_3O = Ag_3PO_4 + 3NO_2Cl.$$

we obtain phosphate of silver, and nitroxyl chloride.

Phosphorus forms with iodine PI_3 and PI_5, with bromine PBr_3, and PBr_5, and it burns spontaneously in those bodies. By the action of sulphuretted hydrogen (H_2S) upon phosphoric chloride PCl_5—a substance termed phosphoric sulpho-chloride $PSCl_3$ is obtained.

Phosphorus forms several compounds with sulphur, two of them P_2S_3, and P_2S_5, corresponding in composition with the oxides P_2O_3, and P_2O_5.

ARSENICUM. ARSENIC.

Symbol, As. Combining weight, 75. Vapour density, 150.

Description.—This substance closely resembles phosphorus in its chemical properties and in its modes of combination, but in its physical characters it presents a strong analogy to the metals; a triad element; rarely or never occurring native, being usually found in combination as mispickel, (FeAsS), a compound of iron, arsenic, and sulphur; tin-white cobalt ($CoAs_2$), cobalt and arsenic; cobalt-glance (CoSAs), cobalt, sulphur, and arsenic; nickel-glance (NiSAs), nickel, sulphur, and arsenic; kupfer-nickel (NiAs), nickel and arsenic; arsenical nickel ($NiAs_2$), nickel and arsenic. It is also contained in very small quantities in many mineral springs.

Preparation.—By heating the arsenious tri-oxide (As_2O_3) mixed with charcoal (C) in a closed crucible, of which the upper part is kept cool. Thus:—

$$As_2O_3 + 3C = 3CO + 2As.$$

Carbonic oxide and arsenicum are formed, the latter of which condenses at the upper part of the apparatus as a brilliant steel-grey solid. When exposed to the air, arsenicum tarnishes by oxidation. Its specific gravity is 5·7. Heated to dull redness it entirely volatilizes, without fusion, as a colourless vapour possessing the odour of garlic.

If heated in the air, As burns with a bluish flame, forming As_2O_3 arsenic tri-oxide.

THE COMPOUNDS OF ARSENIC WITH OXYGEN ARE TWO, VIZ.:—

As_2O_3—Arsenic tri-oxide, arsenious anhydride.

As_2O_5—Arsenic pent-oxide, arsenic anhydride.

ARSENIC TRIOXIDE, ARSENIOUS ANHYDRIDE.

Symbol, As_2O_3. Molecular weight, 198. Vapour density, 198.

Description.—This substance occurs in two modifications, viz.:—

1 The *crystalline*, in brilliant octahedra.

2. The *Vitreous*, without crystalline structure; a semi-transparent glass-like solid, becoming opaque, like porcelain, upon standing.

Preparation.—(1) By burning arsenicum (As) in air.

(2) By roasting arsenical ores and purifying by sublimation; As_2O_3 is very feebly soluble in cold water, and, even in

boiling water has a tendency to float in film. With water, arsenious anhydride forms arsenious acid (H_3AsO_4). Thus:—

$$As_2O_3 + 3H_2O = 2H_3AsO_3.$$

This acid has a feeble reaction, and dissolves in hydrochloric acid; it is freely soluble in solutions of the alkalies, forming arsenites. All these soluble arsenites are fearfully poisonous.

If As_2O_3 be heated to about 220°C, it volatilizes, forming a odourless, inodorous vapour.

The tests for arsenious acid may be divided into 3 groups:—

(1) Solid; (2) Liquid, and (3) Special.

The solid tests are two in number:—

(1) Arsenious acid, heated upon charcoal, emits an odour of garlic.

(2) As_2O_3 is heated in a reduction tube with black flux, *i.e.*, dried carbonate of soda and charcoal. Metallic As is formed and condenses as a ring upon the cool part of the tube.

The liquid tests are three:—

(1) Sulphuretted Hydrogen (H_2S) gives a *yellow* precipitate of sulphide of arsenic (As_2S_3) soluble in ammonia.

(2) Ammonio-nitrate of silver (made by adding just enough liquor ammoniæ to the nitrate of silver to precipitate the brown oxide of silver (Ag_2O)), gives a canary yellow precipitate of arsenite of silver, (Ag_3AsO_3) soluble in excess of ammonia.

(3) Ammonio-sulphate of copper, (made by adding to the sulphate of copper just enough liquor ammoniæ to precipitate the pale-blue hydrated oxide of copper (CuH_2O_2)) gives a *green* precipitate of arsenite of copper or Scheele's green ($CuHAsO_3$) soluble in excess of ammonia.

The special tests are two:—

(1) Marsh's test. This consists in the decomposition of arsenious acid by means of nascent hydrogen. A suitable vessel is taken, and in it are placed some strips of zinc with water and sulphuric acid. Hydrogen is thus generated and escapes through a gas-jet with which the vessel is furnished. This gas burns with a very faint flame when a light is applied, the result of its combustion being only a few drops of water. The arsenious acid is now added to the contents of the vessel. The hydrogen flame is converted into arseniuretted hydrogen, (AsH_3), and burns with a *deep blue* flame. A white porcelain plate is now placed over this last flame, and a deposit is formed which may be divided into three rings. Thus:—

A central ring consisting of metallic arsenic, a ring round this consisting of a mixed deposit of As and As_2O_3, and an external ring of As_2O_3. This deposit is soluble in a solution of chlorinated lime.

(2.) Reinsch's test. This consists in boiling bright strips of copper in an arsenical solution previously acidulated by hydrochloric acid. The metal arsenicum becomes deposited upon the strips of copper, which are then withdrawn and placed in a reduction tube with the same result as has been described above under the solid tests.

ARSENIC PENTOXIDE. ARSENIC ANHYDRIDE.

Symbol, As_2O_5. Molecular weight, 230.

Description.—A white deliquescent non-crystalline powder, decomposing when strongly heated into arsenious anhydride (As_2O_3) and oxygen (O.)

Preparation.—By acting upon As_2O_3 with strong nitric acid (HNO_3). Thus—

$$As_2O_3 + 2HNO_3 = H_2O + N_2O_3 + As_2O_5$$

water, nitrogen trioxide, and arsenic anhydride are formed.

As_2O_5 dissolves in water, and forms arsenic acid, H_3AsO_4. Thus—

$$As_2O_5 + 3H_2O = 2H_3AsO_4.$$

This acid may be also prepared by the action of dilute nitric acid upon As_2O_3. Thus—

$$As_2O_3 + 2H_2O + 2HNO_3 = N_2O_3 + 2H_3AsO_4$$

nitrogen trioxide, and arsenic acid are formed.

With nitrate of silver, arsenic acid gives a *chocolate-red* precipitate of arseniate of silver.

H_3AsO_4 is a poison, but less energetic than H_3AsO_3.

ARSENIC WITH CHLORINE
forms
ARSENIOUS CHLORIDE $AsCl_3$.

This substance can be prepared—(1) by the combustion of arsenicum in chlorine gas, or (2), by distilling As with mercuric chloride ($HgCl_2$). Thus—

$$4As + 12HgCl_2 = 12HgCl + 4AsCl_3$$

mercurous chloride and arsenious chloride are formed.

Corresponding compounds with bromine ($AsBr_3$), iodine (AsI_3) and fluorine (AsF_3), are also known.

ARSENIC WITH HYDROGEN
forms
ARSENIURETTED HYDROGEN, AsH_3.

This gas has been, to some extent, described under Marsh's test. Its preparation may be expressed as follows—

$$Zn_3As_2 + 2H_2SO_4 = 3ZnSO_4 + AsH_3.$$

Arsenite of zinc and sulphuric acid yield sulphate of zinc and arseniuretted hydrogen.

Arsenic with sulphur forms three compounds:

(1) Di-arsenicum di-sulphide, As_2S_2, occurring native in ruby-red crystals, as "Realgar."

(2) Arsenious sulphide, As_2S_3, called also "sulph-arsenious anhydride" and occurring native as a yellow solid or "Orpiment."

(3) Arsenic sulphide As_2S_5, or "sulph-arsenic anhydride"; a yellow substance obtained by fusing sulphur (S_2) with As_2S_3.

A general chemical analogy between nitrogen, phosphorus and arsenic, will be observed in the examination of their oxides, hydrides and chlorides, viz.—

N_2O_3	P_2O_3	As_2O_3.
N_2O_5	P_2O_5	As_2O_5.
NH_3	PH_3	AsH_3.
NCl_3?	PCl_3	$AsCl_3$.

BORON.

Symbol, B. Combining weight, 11.

Description.—A triad element; never native; is found united with oxygen and sodium, as borax; and with oxygen alone as boron trioxide; occurs in three modifications—

(1) *Amorphous boron*, a dull grey powder, which when strongly heated in air burns to boric oxide (B_2O_3).

Prepared by heating the fused boron trioxide (B_2O_3) with metallic sodium (Na). Thus—

$$B_2O_3 + 6Na = 3Na_2O + 2B.$$

Soda and (amorphous) boron result.

(2) *Graphitoidal boron*, in scales with graphite-like lustre.

Prepared by heating boron trichloride (BCl_3), with aluminium (Al). Thus—

$$2Al + 2BCl_3 = 2AlCl_3 + 2B.$$

Chloride of aluminium and (graphitoidal) boron result.

(3) *Diamond boron*, in square octahedra of cupreous lustre; hard enough to scratch a ruby.

Prepared by heating boron tri-oxide (B_2O_3) with aluminium (Al). Thus—

$$B_2O_3 + 2Al = Al_2O_3 + 2B.$$

Alumina and (diamond) boron result.

Boron, when heated strongly in chlorine or oxygen, takes fire, forming the chloride or oxide. It is remarkable for uniting directly with nitrogen, which gas it absorbs when red hot with the evolution of light, forming—

BORON NITRIDE.

Symbol, BN.

This is a grey mass, and may also be prepared by heating borax ($Na_2B_4O_7$) with chloride of ammonium (NH_4Cl). Thus—

$$Na_2B_4O_7 + 4NH_4Cl = 2NaCl + 2HCl + 7H_2O + 4BN.$$

Chloride of sodium, hydrochloric acid, water, and boron nitride are formed.

BORON WITH CHLORINE
forms a liquid called

BORON TRI-CHLORIDE.

Symbol, BCl_3.

Prepared from boron trioxide (B_2O_3), chlorine (Cl), and carbon (C), at a bright red heat. Thus—

$$B_2O_3 + 6Cl + 3C = 3CO + 2BCl_3.$$

Carbonic oxide and boron trichloride result.

BORON WITH FLUORINE
forms

BORON TRI-FLUORIDE.

Symbol, BF_3.

An irritating, colourless, irrespirable gas, fuming in air; with water it forms

HYDRO-FLUO-BORIC ACID.

Symbol, HBF_4.

Thus—

$$4BF_3 + 3H_2O = H_3BO_3 + 3HBF_4.$$

Boracic acid and hydro-fluo-boric acid result.

BORON WITH OXYGEN
forms

BORON TRIOXIDE. BORACIC ANHYDRIDE.

Symbol, B_2O_3. Molecular weight, 70.

This fuses to a glass, which retains its clearness on cooling. It is prepared by heating boracic acid (H_3BO_3). Thus—

$$2H_3BO_3 = 3H_2O + B_2O_3.$$

Water and boron trioxide result.

WITH WATER B_2O_3
forms

BORIC OR BORACIC ACID.

Symbol, H_3BO_3. Molecular weight, 62.

Description.—A tribasic acid, crystallising in pearly plates from the solution as it cools.

Found in the fumerolles or soffioni (steam jets), which are constantly escaping from the earth in old volcanic districts of Tuscany, and which collect in the lagoons at the mouth of these jets. The boracic acid is concentrated by the heat of the natural steam jets, and the acid obtained by crystallisation.

Tinkal or sodium borate also occurs in California and Thibet.

A solution of H_3BO_3 in alcohol, when ignited, communicates a green colour to the flame.

This acid is slightly soluble in cold water, but rather more so in hot water.

Boracic acid may also be prepared by the addition of hydrochloric acid (HCl) to a hot solution of borax ($Na_2B_4O_7$). Thus—

$$Na_2B_4O_7 + 2HCl + 5H_2O = 2NaCl + 4H_3BO_3.$$

Chloride of sodium and boracic acid result.

BORAX. BIBORATE OF SODA.

Symbol, $Na_2B_4O_7, 10H_2O$.

As has been stated above, this substance is a compound of sodium boron and oxygen. It is a native salt, but can be artificially prepared by heating together boracic acid (H_3BO_3), and carbonate of soda (Na_2CO_3). Thus—

$$4H_3BO_3 + Na_2CO_3 = 6H_2O + CO_2 + Na_2B_4O_7.$$

Water, carbonic anhydride, and borax result.

Borax is much used as a blow-pipe re-agent in the laboratory, since many metallic oxides are soluble in fused borax, yielding coloured glasses as follows—

BORAX BEADS.

	Oxidizing, or Outer Flame.		*Reducing, or Inner Flame.*	
	Hot.	*Cold.*	*Hot.*	*Cold.*
Chronium (Cr)	Green	Green	Green	Green
Cobalt (Co)	Blue	Blue	Blue	Blue
Nickel (Ni)	Violet	Reddish-brown	Colourless	Grey and turbid
Copper (Cu)	Green	Blue	Colourless	Brownish-red from Metallic Cu
Iron (Fe)	Brownish-red	Light yellow	Red (Yellowish	Bottle-green on cooling)
Manganese (Mn)	Amethyst-red or Violet	Amethyst-red	Colourless (but not	Colourless quite clear)
Silver (Ag)	Yellowish to Opal	Rather dull	Colourless	Whitish-grey
Gold (Au) Platinum (Pt)	Are reduced in all flames, the Au showing blueish-green by transmitted light, and reddish by reflected.			

SILICON.

Symbol, Si. Combining weight, 28.

Description.—A tetrad element; never native, but combined with oxygen as silica (SiO_2). Exists nearly pure in rock crystal or quartz, in sand, flint, and many minerals; also found combined with the metals and oxygen, as silicates. The most abundant element known next to oxygen. There are three modifications of silicon, viz.—

(1) *Amorphous silicon.*—A brown powder, only acted upon by hydrofluoric acid (HF), which dissolves it.

Prepared by acting upon silico-fluoric acid ($(HF)_2,SiF_4$), with metallic potassium (K.). Thus—

$$(KF)_2,SiF_4 + 4K = 6KF + Si.$$

Fluoride of potassium, and (amorphous) silicon result.

(2) *Graphitoidal silicon.*—Hexagonal plates with metallic lustre.

Prepared by fusing the amorphous form with aluminium (Al), and dissolving the latter in hydrochloric acid.

(3) *Adamantine silicon,* in steel-grey crystals, hard enough to scratch glass. Prepared by heating aluminium (Al), in the vapour of silicon tetrachloride ($SiCl_4$). Thus—

$$3SiCl_4 + 4Al = 2Al_2Cl_6 + 2Si.$$

Chloride of aluminium and (adamantine) silicon result.

SILICON WITH OXYGEN
forms
SILICIC ANHYDRIDE, SILICON DIOXIDE, OR SILICA.

Symbol, SiO_2. Molecular weight, 60.

Description.—A snow-white, gritty, insoluble powder, almost infusible, but soluble in hydrofluoric acid (HF). Prepared by heating silicic acid (H_2SiO_3). Thus—

$$H_2SiO_3 + \text{heat} = H_2O + SiO_2.$$

Water and silica are formed.

SiO_2 also exists in a crystallised form, as white transparent quartz.

SILICA WITH WATER
forms two acids, viz.—

(1) Meta-silicic acid ($SiO_2 + H_2O = H_2SiO_3$.)

(2) Ortho-silicic acid ($SiO_2 + 2H_2O_4 = H_4\ SiO$).

META-SILICIC ACID.

Symbol, H_2SiO_3.

Description.—A clear limpid fluid, with a tendency to become gelatinous.

The chief agent in petrifaction.

Preparation.—By acting upon potassium silicate (K_2SiO_3), by sulphuric acid (H_2SO_4) Thus—

$$K_2SiO_3 + 2HCl = 2KCl + H_2SiO_3.$$

Chloride of potassium, and meta-silicic acid are formed.

This acid must be prepared by

DIALYSIS.

By this term is implied a process used in chemistry for the separation of bodies. It is dependent upon the fact that all crystallisable substances, termed *crystalloids*, will pass in solution through a parchment paper; whilst all gum-like amorphous substances termed *colloids*, such as gelatinous-silicic acid, will not so pass.

The *dialyzer* used in this process consists of a flat sieve, or drum, constructed of parchment paper into which the substances are thrown, the drum being then floated upon a large surface of water.

ORTHO-SILICIC ACID.

Symbol, H_4SiO_4.

A white and gelatinous substance, when first precipitated and soluble until evaporated to dryness.

Prepared by leading silicon tetra-fluoride (SiF_4) into water. Thus—

$$3SiF_4 + 4H_2O = 2H_2SiF_6 + H_4SiO_4.$$

Ortho-silicic acid is formed, together with a new acid, H_2SiF_6, to which the name of *hydro-fluo-silicic* acid is given.

SILICON WITH HYDROGEN
forms
SILICIURETTED HYDROGEN. SILICON HYDRIDE.

Symbol, SiH_4.

Is a colourless gas, inflaming spontaneously in the air, and forming water and silica, the latter separating as a white ring-shaped cloud. It is prepared by acting upon a compound of magnesium and silicon (Mg_2Si), with hydrochloric acid. Thus—

$$Mg_2Si + 4HCl = 2MgCl_2 + SiH_4.$$

Chloride of magnesium and silicon hydride result.

SILICON WITH CHLORINE
forms
SILICON TETRACHLORIDE.

Symbol, $SiCl_4$. Molecular weight, 170. Density, 85.

A colourless, pungent, irritating liquid, formed when silicon is heated in chlorine, but may also be prepared by passing dry chlorine over a red-hot mixture of carbon (C), and finely divided silica (SiO_2). Thus—

$$4Cl + 2C + SiO_2 = 2CO + SiCl_4.$$

Carbonic oxide and silicon tetra-chloride result.

By passing dry hydrochloric-acid gas over silicon, heated to dull redness, a new substance is formed, termed

SILICON CHLOROFORM.

Symbol, $SiHCl_3$.

Analogous in composition to ordinary chloroform ($CHCl_3$). This is very inflammable, and burns with a greenish flame, evolving white clouds of silica. By water it is decomposed into a white powder, *silicon-formic-anhydride* ($Si_2H_2O_3$).

SILICON WITH FLUORINE
forms
SILICON TETRA-FLUORIDE.

Symbol, SiF_4. Molecular weight, 104. Density, 52.

Description.—A colourless, pungent gas, fuming strongly in air, always formed whenever hydrofluoric acid comes in contact with silica.

Preparation.—By heating fluoride of calcium (CaF_2) with sand (SiO_2), and sulphuric acid (H_2SO_4). Thus—

$$2CaF_2 + SiO_2 + 2H_2SO_4 = 2CaSO_4 + 2H_2O + SiF_4.$$

Sulphate of lime, water, and silicon tetra-fluoride, are formed.

This substance is decomposed by water, but may be collected over mercury, or by displacement.

A corresponding compound of silicon with bromine is also known, called *silicon bromide*, $SiBr_4$.

With sulphur, silicon forms silicon sulphide (SiS_2), a white, earthy mass, decomposed by water into sulphuretted hydrogen, and ortho-silicic acid.

SELENIUM.

Symbol, Se. Combining weight, 79·5. Density, 79·5.

Description.—A brownish-red, semi-transparent substance, with a metallic lustre, closely allied to sulphur in its properties. A dyad element, and only found in small quantities. When burnt in the air it gives off an odour of decaying horse-radish, and exhibits a bright blue flame, which displays magnificent bands in the spectrum. The vapour condenses to red flowers.

Preparation.—By acting upon selenious acid (H_2SeO_3) with water (H_2O), and sulphurous anhydride (SO_2). Thus—

$$H_2SO_3 + 2SO_2 + H_2O = 2H_2SO_4 + Se.$$

Sulphuric Acid and Selenium are formed.

SELENIUM WITH OXYGEN
forms two oxides, viz.—

(1) SeO_2. Selenium dioxide.
(2) SeO_3. Selenium trioxide.

SELENIUM DIOXIDE.

Symbol, SeO_2. Molecular weight, 111·5.

Description.—A white, crystalline mass, soluble in water. It may be prepared by burning selenium in air, or oxygen, or by the oxidation of this substance by nitric acid.

SELENIOUS DIOXIDE WITH WATER
forms
SELENIOUS ACID.

Symbol, H_2SeO_3.

A powerful acid, resembling sulphuric.

SELENIUM TRIOXIDE.

Symbol, SeO_3.

Has never been isolated, but an acid is known, called—

SELENIC ACID.

Symbol, H_2SeO_4.

This is also like sulphuric acid. In the reducing flame of the blow-pipe, it emits the odour of selenium. It is a solvent of gold, but not of platinum.

Preparation.—By the addition of sulphuretted hydrogen (H_2S), to selenate of lead ($PbSeO_4$). Thus—

$$PbSeO_4 + H_2S = PbS + H_2SeO_4.$$

Sulphide of lead is formed, and upon evaporating the solution, selenic acid is left.

SELENIUM WITH HYDROGEN
forms
HYDROGEN SELENIDE, SELENIURETTED HYDROGEN.

Symbol, H_2Se. Molecular weight, 81·5. Density, 40·75.

Description.—A colourless, inflammable gas, with a nauseous smell, exciting catarrh, and destroying the sense of smell. Decomposes metallic solutions, like sulphuretted hydrogen.

Preparation.—From selenide of iron (FeSe), by the action of sulphuric acid (H_2SO_4). Thus—

$$FeSe + H_2SO_4 = FeSO_4 + H_2S.$$

Sulphate of iron, and seleniuretted hydrogen result.

TELLURIUM.

Symbol, Te. Combining weight, 129. Density, 129.

Description.—A very rare substance of silvery, brittle, metallic, appearance. Is found combined with gold, silver, and bismuth, in Transylvania and Hungary. When administered internally, it communicates to the breath a garlic odour.

Tellurium dissolves in cold, concentrated, sulphuric acid, to which it imparts a fine purple colour. It forms with oxygen, two oxides.

(1) TELLURIUM DIOXIDE.

Symbol, TeO_2.
Formed when tellurium is oxidised by nitric acid.
TeO_2, with water, forms TELLUROUS ACID (H_2TeO_3).

(2) TELLURIUM TRIOXIDE.

Symbol, TeO_3.
Forms, with water, TELLURIC ACID $H_2TeO_4 + 2H_2O$.

WITH HYDROGEN, TELLURIUM forms TELLURETTED HYDROGEN.

Symbol, H_2Te.
A colourless gas, smelling exactly like sulphuretted hydrogen.

It will be noticed that oxygen, sulphur, selenium, and tellurium, each unite with two atoms of hydrogen, to produce an analogous series of bodies, viz.—

$$H_2O;\ H_2S;\ H_2Se;\ H_2Te.$$

And of the three, sulphur, selenium, and tellurium, the mean of the combining weight of the extremes is nearly that of the mean, viz.—

$$\frac{32 + 129}{2} = 80{\cdot}5.$$

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

The *metre* is a unit of length, equal to a little more than one yard, viz., 39·37 English inches. Its length is arbitrary, but a standard metre has been prepared, and of this copies are in use. The French geometricians first intended that the length of this metre should have some reference to the circumference of the earth, and they, therefore, caused a standard to be made having the length of the $\frac{1}{10\,000\,000}$ of the distance from the equator to the pole. It has been subsequently proved that the metre is not quite, although very nearly, the $\frac{1}{10\,000\,000}$ part of this distance.

The metre is divided into tenths, *decimetres*, hundredths, *centimetres*, and thousandths, *millimetres*. The multiples of the metre, tens, hundreds, and thousands are termed *decametres*, *hectometres*, and *kilometres* respectively.

We can easily obtain the measures of *area* and *capacity*, and thus we have *square* metres, and *square* deci-, centi-, and milli-, metres; and also *cubic* metres and *cubic* deci-, centi-, and milli-metres.

10	decimetres	1 metre.
100	centimetres	„
1,000	millimetres	„
100	square decimetres	1 square metre.
10,000	„ centimetres	„
1,000,000	„ millimetres	„
1,000	cubic decimetres	1 cubic metre.
1,000,000	„ centimetres	„
1,000,000,000	„ millimetres	„

The *litre* is a term used to denote 1 cubic decimetre, which is rather less than a quart English.

The arrangers of this system were desirous of obtaining a simple relation between the measure of volume and that of weight, and they, therefore, took as their unit of weight *the weight of* 1 *cubic centimetre* of water at the temperature of 4° centigrade, and they called this *a gramme*. Like the metre, this gramme is divided into tenths, hundredths, and thousandths, called deci-, centi-, and milli-, gram; the tens, hundreds, and thousands are called deca-, hecto-, and kilo-, gram.

MEASUREMENT OF TEMPERATURE.

We ascertain the measurements of changes of temperature by the expansion or contraction which bodies undergo by alternations of temperature. Liquids are generally used for this purpose, since gases expand too much, and solids too little. We commonly employ alcohol and mercury, especially the latter, since its rate of expansion is almost uniform, and because it boils at a very high temperature (350°), and freezes at a comparatively low one (—39·4°), and is, therefore, capable of measuring a large range of temperature. We use alcohol for the measurement of very low temperatures, since it has never been frozen. It is only in very delicate experiments in physics that air thermometers are employed.

The Mercurial Thermometer.

To prepare this a straight piece of glass-tubing is taken, with as uniform a bore as possible, and a bulb is blown upon the end. The bulb and the whole of the tube are filled with mercury, and heated to the highest temperature we require to measure. The open end of the tube, full of mercury, is then completely closed, the glass being melted before the blowpipe. We now have *to graduate* the thermometer, and this is performed as follows—

(1) The bulb and stem are plunged *into finely-powdered melting ice*, and the stem marked at the point where the mercury stands.

(2) The bulb and stem are immersed *in the steam given off from water boiling in a metallic vessel*, and the stem marked where the mercury then stands.

There are three thermometric scales at present in use, each of which can be expressed in terms of the other, viz.—

1. Centigrade.
2. Fahrenheit.
3. Réaumur.

In the *Centigrade* scale, the zero is placed at the freezing point, and the boiling point at 100°, so that between these two points there are 100 *degrees*. Above the boiling and below the freezing points divisions equal in size are continued, those below the freezing point being distinguished by a minus sign, viz., — 1°C, — 2°C, &c.

In the *Fahrenheit* scale the freezing point is fixed at 32°, and the boiling point at 212°, so between these points there are 180 degrees.

In the *Réaumur* scale we have 80° between the boiling and freezing points. The freezing point is zero, and the boiling point 80°.

The numbers 9, 5, 4 consequently express the relation between degrees Fahrenheit, Centigrade, and Réaumur. Now, 180° Fahrenheit equals 100° Centigrade, *i.e.*, 1° F $= (\frac{100}{180})\ \frac{5}{9}$ C; and 1° C $= (\frac{180}{100})\ \frac{9}{5}$ F. We, therefore, multiply Fahrenheit degrees by $\frac{5}{9}$ to reduce them to Centigrade, and Centigrade degrees by $\frac{9}{5}$ to reduce them to Fahrenheit. But while on the centigrade scale the zero is at the freezing point of water, on the Fahrenheit scale it is at 32°. We must, therefore, add or subtract 32 according to circumstances, in order to obtain the same starting point. In short—

(1) In converting Fahrenheit into Centigrade degrees, subtract 32 from the number of the degrees, and multiply the remainder by $\frac{5}{9}$.

(2) In converting Centigrade to Fahrenheit degrees, multiply the number of degrees by $\frac{9}{5}$, and add 32 to the product.

To take examples: Alcohol boils at 173° F, what is this on the Centigrade scale?

$$173^\circ - 32 = 141^\circ, \text{ and } 141^\circ + \tfrac{5}{9} = 78{\cdot}3^\circ \text{ C.}$$

Again, mercury freezes at − 39·4° C, what is this on the Fahrenheit scale?

$$-\ 39{\cdot}4^\circ + \tfrac{9}{5} = -\ 70{\cdot}9^\circ \text{ and } -\ 70{\cdot}9^\circ + 32 = -\ 38{\cdot}9^\circ \text{ F.}$$

EXPANSION OF GASES BY HEAT.

Gases expand much more for equal increments of heat than solids or liquids; all gases expand alike or nearly so, while solids and liquids all expand differently. Exact and labourious experiments have shown that all gases expand $\frac{1}{273}$ part of their volume at 0° C for every increase in temperature of 1° Centigrade.

	273	volumes of air or Hydrogen	at	0° C.
Become	274	„	„	1° C.
„	275	„	„	2° C.
„	276	„	„	3° C.
Or	273 + t	„	„	t° C.

The corresponding decimal fraction to $\frac{1}{273}$ is 0·003,665; 1 volume of air at 0°C becomes 1·003,665 volumes when heated to 1° C. The *co-efficient of the expansion of gases* is the name given to this fraction. Suppose we wish to know the volume which 1,000 cubic centimetres of H measured at 0°C will occupy when the temperature is raised to 20°, we have an alteration in bulk in the ratio of the numbers 273 to 273 + 20. We, therefore, multiply 1,000 by 293, and divide by 273. Should we wish to know what volume 1,000 cubic centimetres, measured at 20°C, will occupy when the temperature sinks to 0°; we know that diminution in volume follows the same law; therefore, 293 volumes at 20° will become 273 volumes at 0°.

RELATION OF VOLUME OF GASES TO PRESSURE.

Gases are known as *compressible bodies*, because when they are subjected to pressure their volume becomes less, and upon the withdrawal of the pressure they again expand. Solids and liquids cannot be compressed in the same way, and are hence called *incompressible*. Boyle's or Mariotte's law states that *the volume occupied by any gas is inversely proportional to the pressure to which it is subjected*. The volume 1 under pressure 1 becomes the volume 2 under the pressure $\frac{1}{2}$, the volume 3 under the pressure $\frac{1}{3}$, the volume $\frac{1}{2}$ under the pressure 2, and the volume $\frac{1}{3}$ under the pressure 3, and so on.

DIFFUSION OF GASES.

When gases are mixed together, and do not combine chemically, they have the power of becoming intimately mixed together, even when the heavier gas is placed at the bottom, and both remain undisturbed. This property illustrates the *diffusive power of gases*. The rate of diffusion is subject to variation. A bottle of carbonic acid lost only 47 per cent. of gas when left exposed to the air in the same time that a bottle of hydrogen lost 94·5 in the same way. Gaseous diffusion will take place through such solids as stucco, or thin plates of graphite. Experiments show that *the velocity of diffusion of different gases is inversely proportional to the square roots of their densities;* Oxygen being 16 times as heavy as hydrogen, 4 volumes of the latter will pass through the diaphragm in the same time that one volume of the former will be able to do so.

Finis of Part I.

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AIDS
TO
CHEMISTRY.

SPECIALLY DESIGNED FOR
STUDENTS PREPARING FOR EXAMINATIONS.

PART II.—INORGANIC:
THE METALS.

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1878.

PREFACE.

THE contents of the following pages are simply intended as an introduction to an elaborate, and, I may say, an almost unlimited science. They are simply an abstract of lectures delivered to my pupils during the last five years. Many of the metals, as Vanadium, Titanium, Tungsten, and others, have been purposely omitted, the endeavour having been, throughout the work, to embrace as many of the leading facts as possible, and to ignore all details of apparently minor importance.

Contributions have been freely levied upon the admirable works of Miller, Fownes, Roscoe, Bernays, and especially upon the "Chemia Coartata" of Professor Kollmyer, from whose "Key to Modern Chemistry" I have derived much useful information concerning the tests for the metals.

I am fully aware how infinitesimal is the amount of justice that it is possible to bestow upon the chemistry of the metals in the few following pages, and I can only hope that the present volume may prove serviceable to the tyro upon the threshold of his study.

C. E. A. S.

8, TORRINGTON SQUARE, W.C.
March, 1878.

O CHEMISTRY.

E METALS.

an 50 known metals, but inasmuch as
nd only in very small quantities, and
t little ascertained, the most important
l in the following pages.
mercury, are solid at ordinary tempera-
d conductors of heat and electricity ;
of being polished, and of reflecting light ;
giving rise to the so-called metallic
ally dense and heavy, ductile, malleable
ll opaque, except in the very thinnest
af, through which light is capable of
considerably from one another, both in
properties ; the lightest presenting the
rs with oxygen ; the heavier, the re-

metallic salt be decomposed by elec-
ll invariably be found at the negative
etals are electro-positive. A salt is
ion of a metal with a non-metallic
efined as the union of an electro-positive
ve.
acid terminate in *ous*, as sulphurous,
ulting salt is termed an *ite*. If the acid
sulphuric, nitric, etc., the salt then
te; either being *sub—mono—sesqui—di—*
r sulphate, according to circumstances.
termed *Haloid salts* have already been
gens.

THE METALS.

Kalium. Natrium.	Lithium. Ammonium.	Cæsium. Rubidium.

Calcium.	Strontium.	Barium.

ALUMINIUM.

Magnesium.	Zincum.	Cadmium.

Manganesium. Ferrum.	Cobaltium. Nickel.	Chromium.

Stannum.

Stibium.	Bismuthum.

Plumbum.

Cuprum.	Hydrargyrum.	Argentum.

Aurum.	Platinum.

AIDS TO CHEMISTRY.

THE METALS.

THERE are no less than 50 known metals, but inasmuch as some of these are found only in very small quantities, and their properties are but little ascertained, the most important only will be considered in the following pages.

All metals, except mercury, are solid at ordinary temperatures. They are good conductors of heat and electricity; many are susceptible of being polished, and of reflecting light; in the latter quality giving rise to the so-called metallic lustre. They are usually dense and heavy, ductile, malleable and tenacious; are all opaque, except in the very thinnest films, as with gold-leaf, through which light is capable of passage. They differ considerably from one another, both in chemical and physical properties; the lightest presenting the greatest uniting powers with oxygen; the heavier, the reverse.

If a solution of a metallic salt be decomposed by electrolysis, the metal will invariably be found at the negative pole, proving that metals are electro-positive. A salt is formed by the junction of a metal with a non-metallic element, and may be defined as the union of an electro-positive with an electro-negative.

If the name of the acid terminate in *ous*, as sulphurous, nitrous, etc., the resulting salt is termed an *ite*. If the acid terminate in *ic*, as sulphuric, nitric, etc., the salt then receives the name of *ate;* either being *sub—mono—sesqui—di—tri—tetra—*sulphite or sulphate, according to circumstances.

Those substances termed *Haloid salts* have already been described under Halogens.

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In the *Réaumur* scale we have 80° between the boiling and freezing points. The freezing point is zero, and the boiling point 80°.

The numbers 9, 5, 4 consequently express the relation between degrees Fahrenheit, Centigrade, and Réaumur. Now, 180° Fahrenheit equals 100° Centigrade, *i.e.*, 1° F $= (\frac{100}{180}) \frac{5}{9}$ C; and 1° C $= (\frac{180}{100}) \frac{9}{5}$ F. We, therefore, multiply Fahrenheit degrees by $\frac{5}{9}$ to reduce them to Centigrade, and Centigrade degrees by $\frac{9}{5}$ to reduce them to Fahrenheit. But while on the centigrade scale the zero is at the freezing point of water, on the Fahrenheit scale it is at 32°. We must, therefore, add or subtract 32 according to circumstances, in order to obtain the same starting point. In short—

(1) In converting Fahrenheit into Centigrade degrees, subtract 32 from the number of the degrees, and multiply the remainder by $\frac{5}{9}$.

(2) In converting Centigrade to Fahrenheit degrees, multiply the number of degrees by $\frac{9}{5}$, and add 32 to the product.

To take examples: Alcohol boils at 173° F, what is this on the Centigrade scale?

$$173° - 32 = 141°, \text{ and } 141° + \tfrac{5}{9} = 78{\cdot}3° \text{ C.}$$

Again, mercury freezes at − 39·4° C, what is this on the Fahrenheit scale?

$$- 39{\cdot}4° + \tfrac{9}{5} = - 70{\cdot}9° \text{ and } - 70{\cdot}9° + 32 = - 38{\cdot}9° \text{ F.}$$

EXPANSION OF GASES BY HEAT.

Gases expand much more for equal increments of heat than solids or liquids; all gases expand alike or nearly so, while solids and liquids all expand differently. Exact and labourious experiments have shown that all gases expand $\frac{1}{273}$ part of their volume at 0° C for every increase in temperature of 1° Centigrade.

	273	volumes of air or	Hydrogen at	0° C.
Become	274	”	”	1° C.
”	275	”	”	2° C.
”	276	”	”	3° C.
Or	273 + t	”	”	t° C.

The corresponding decimal fraction to $\frac{1}{273}$ is 0·003,665; 1 volume of air at 0°C becomes 1·003,665 volumes when heated to 1° C. The *co-efficient of the expansion of gases* is the name given to this fraction. Suppose we wish to know the volume which 1,000 cubic centimetres of H measured at 0°C will occupy when the temperature is raised to 20°, we have an alteration in bulk in the ratio of the numbers 273 to 273 + 20. We, therefore, multiply 1,000 by 293, and divide by 273. Should we wish to know what volume 1,000 cubic centimetres, measured at 20°C, will occupy when the temperature sinks to 0°; we know that diminution in volume follows the same law; therefore, 293 volumes at 20° will become 273 volumes at 0°.

RELATION OF VOLUME OF GASES TO PRESSURE.

Gases are known as *compressible bodies*, because when they are subjected to pressure their volume becomes less, and upon the withdrawal of the pressure they again expand. Solids and liquids cannot be compressed in the same way, and are hence called *incompressible.* Boyle's or Mariotte's law states that *the volume occupied by any gas is inversely proportional to the pressure to which it is subjected.* The volume 1 under pressure 1 becomes the volume 2 under the pressure $\frac{1}{2}$, the volume 3 under the pressure $\frac{1}{3}$, the volume $\frac{1}{2}$ under the pressure 2, and the volume $\frac{1}{3}$ under the pressure 3, and so on.

DIFFUSION OF GASES.

When gases are mixed together, and do not combine chemically, they have the power of becoming intimately mixed together, even when the heavier gas is placed at the bottom, and both remain undisturbed. This property illustrates the *diffusive power of gases.* The rate of diffusion is subject to variation. A bottle of carbonic acid lost only 47 per cent. of gas when left exposed to the air in the same time that a bottle of hydrogen lost 94·5 in the same way. Gaseous diffusion will take place through such solids as stucco, or thin plates of graphite. Experiments show that *the velocity of diffusion of different gases is inversely proportional to the square roots of their densities;* Oxygen being 16 times as heavy as hydrogen, 4 volumes of the latter will pass through the diaphragm in the same time that one volume of the former will be able to do so.

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LITHIUM—(Lithos, a stone).

Symbol, Li. Combining weight, 7. Specific gravity, 0·59.

Description, Sources, etc.—A soft reddish-white metal. The lightest solid known; prepared by the decomposition of the fused chloride by electricity. It occurs in two minerals called *spodumene* and *petalite*, and in small quantities in almost all waters, in tobacco, milk, and human blood.

All the volatile compounds of lithium give a splendid crimson to flame, and the spectrum presents one bright red line by which the minutest trace of lithium may be detected.

AMMONIUM—(From Jupiter Ammon).

In all the ammoniacal salts the existence of a quasi-metal *Ammonium* (NH_4) is supposed, since, if we substitute this for an atom of sodium or potassium in the alkaline salts, a corresponding ammonium salt is obtained. Thus—

Potassium Chloride	KCl.	Ammonium Chloride	NH_4Cl.
Potassium Nitrate	KNO_3.	Ammonium Nitrate	NH_4NO_3.
Potassium Sulphate	$\left.\begin{matrix}K\\K\end{matrix}\right\}SO_4$.	Ammonium Sulphate	$\left.\begin{matrix}NH_4\\NH_4\end{matrix}\right\}SO_4$.
Potassium Hydrosulphide	$\left.\begin{matrix}K\\H\end{matrix}\right\}S$.	Ammonium Hydrosulphide	$\left.\begin{matrix}NH_4\\H\end{matrix}\right\}S$.

The radical (NH_4) in the free state is a dark-blue liquid possessing a metallic lustre, but only existing under very high pressure, and at a very low temperature, and readily decomposing into hydrogen (H), and ammonia (NH_3).

An amalgam of ammonium may be obtained by placing sodium amalgam (NaHg) into a solution of chloride of ammonium (NH_4Cl), when chloride of sodium (NaCl) is formed, and the liberated ammonium combines with the mercury to form a light bulky metallic mass (NH_4Hg) which rises to the surface of the liquid, but soon decomposes into mercury (Hg), hydrogen (H) and ammonia (NH_3). The decomposition may be represented thus—

$$NaHg + NH_4Cl = NaCl + NH_4Hg.$$

Sodium amalgam and chloride of ammonium yield chloride of sodium and ammonium amalgam.

AMMONIUM CHLORIDE. SAL-AMMONIAC, NH_4Cl,

Occurs in white tough fibrous masses, difficult to powder, but easily soluble in water; on heating it entirely volatilises without fusion. It is prepared by (1) neutralising the ammoniacal liquor of the gas-works with hydrochloric acid; or, (2) by subliming sulphate of ammonia [$(NH_4)_2SO_4$] with common salt (NaCl). Thus—

$$(NH_4)_2SO_4 + 2NaCl = Na_2SO_4 + 2NH_4Cl.$$

Sulphate of sodium and chloride of ammonium result.

AMMONIUM CARBONATE, $(NH_4)_2CO_3$,

Is a very unstable substance, decomposing in contact with air, with evolution of ammonia.

It is prepared by submitting chloride of ammonium (NH_4Cl) and chalk ($CaCO_3$) to sublimation. Thus—

$$2NH_4Cl + CaCO_3 = CaCl_2 + (NH_4)_2CO_3.$$

Chloride of calcium and carbonate of ammonia are formed.

This $(NH_4)_2CO_3$ absorbs water and carbonic acid gas from the air and passes into the

AMMONIUM HYDROGEN CARBONATE OR BICARBONATE OF AMMONIA, NH_4HCO_3.

This occurs in large crystals, soluble in eight parts of water, and is isomorphous with the corresponding potassium compound.

AMMONIUM NITRATE, NH_4NO_3,

Occurs in long transparent elastic needles, very soluble in water, and when heated above 230° C. decomposes into water (H_2O) and nitrous oxide gas (N_2O). It is prepared by the addition of nitric acid to ammonia.

AMMONIUM PHOSPHATE, $(NH_4)_3PO_4$,

Is formed when ammonia and phosphoric acid are mixed in hot concentrated solutions from which, upon cooling, the salt crystallises out. Upon drying, one molecule of ammonium is lost, and thus is obtained the salt $(NH_4)_2HPO_4$, upon boiling which another molecule of ammonium disappears and we obtain the salt $NH_4H_2PO_4$. Upon ignition all these salts leave a residue of metaphosphoric acid (HPO_3).

Microcosmic salt or ammonium sodium hydrogen phosphate, NH_4NaHPO_4 is much used for blow-pipe experiments.

AMMONIUM SULPHATE, $(NH_4)_2SO_4$,

Occurs in long flat six-sided prisms, very soluble in water. It is prepared by the addition of sulphuric acid to gas-water. It is also a native salt, and is much employed as a manure and for the manufacture of alum.

AMMONIUM SULPHIDE, $(NH_4)_2S$.

This substance separates out in colourless crystals, when dry sulphuretted hydrogen gas and excess of dry ammoniacal gas are brought together at 18° C. At the ordinary temperature this substance loses NH_3 and becomes converted into a crystalline mass of the *hydrosulphide* NH_4HS, a volatile body, and very prone to decompose into ammonia and sulphuretted hydrogen. An aqueous solution is much used as a reagent. This is obtained by saturating aqueous ammonia with sulphuretted hydrogen. The colourless solution soon becomes yellow from the formation of polysulphides of ammonium.

Tests for the Ammonium Compounds—

(1) All the salts are white, are volatilised by heat, and if heated with caustic potash, soda, or lime, yield ammonia gas, known by its pungent odour and alkaline reaction on litmus.

(2) Perchloride of platinum gives a yellow precipitate of ammonio-platino-chloride (NH_4PtCl_6).

(3) Nitrate of silver and a solution of arsenious acid with liquor ammoniæ (NH_4HO) gives a yellow precipitate.

(4) Nessler's test consists in the addition of caustic potash (KHO) together with a solution of mercuric iodide (HgI_2) and potassium iodide (KI) to a solution containing ammonia or any of its salts; a brown colouration or precipitate is instantly produced which consists of dimercur-ammonium-iodide. Thus—

$$4KI + 2HgI_2 + NH_3 + 3KHO = 2H_2O + 7KI + NHg_2I, H_2O.$$

This is a most delicate test.

HYDROXYLAMINE, NH_3O or $N\left\{\begin{array}{l}H\\H\\OH\end{array}\right.$

This substance may be regarded as an intermediate compound between ammonia and water, or as ammonia NH_3 in which one atom of H is replaced by hydroxyl (OH). It acts as a base and unites with acids to form a well-defined series of salts. An aqueous solution of hydroxylamine has been prepared, and forms an inodorous, colourless liquid with strong alkaline reaction, but hydroxylamine itself has never as yet been isolated. It may be prepared synthetically by the direct union of nascent hydrogen (H) and nitric oxide (N_2O_2). Thus—

$$N_2O_2 + 6H = 2NH_3O.$$

The following are the best known salts of hydroxylamine.

NH_3OHCl	Hydrochlorate of Hydroxylamine.
$(NH_3O)_2H_2SO_4$	Sulphate ,, ,,
NH_3OHNO_3	Nitrate ,, ,,
$(NH_3O)_3H_3PO_4$	Phosphate ,, ,,

Cæsium—(Cæsius, sky-blue), and Rubidium—(Rubidus, dark-red).

These metals were discovered by spectrum analysis. They were originally found in the mineral water of Durckheim, but since then have been discovered in many other springs, in varieties of mica, as well as in the ashes of several plants, as the beet-root, tobacco, coffee, grapes. They are prepared by decomposing their fused chlorides by means of electricity.

Cæsium may be separated from rubidium by taking advantage of the greater solubility of the acid tartrate of the former. Cæsium gives two bright lines in the blue of the spectrum. Rubidium gives two bright lines in the red and two in the blue of the spectrum.

General Characteristics of the Metals of the Alkalies.

All the metals of this group are monads. Are soft, volatile at high temperatures and easily fusible. They combine very energetically with oxygen, and decompose water at all temperatures with the formation of basic oxides, which are freely soluble in water, producing powerful caustic alkaline substances termed hydroxides from which it is impossible to expel water by heat. Each metal forms only one chloride, and their carbonates are soluble in water.

Sodium (23), which in its properties stands between potassium (39) and lithium (7), has a combining weight which is the arithmetic mean of the other two. Thus—

$$\frac{39 + 7}{2} = 23.$$

GROUP II.—THE METALS OF THE ALKALINE EARTHS.

Calcium. Strontium. Barium.

CALCIUM—(Calx, lime).

Symbol, Ca. Combining weight, 40. Specific gravity, 1·58.

Description and Sources.—A light yellow metal, readily oxidizing. When heated in the air it burns with a bright white light forming lime (CaO), the only oxide. In combination calcium forms whole mountain chains, and under the forms of limestone, chalk, and gypsum is very extensively diffused over the earth.

Preparation.—(1) By passing an electric current through the fused chloride ($CaCl_2$).

(2) By heating the iodide of calcium (CaI_2) with sodium (Na).

CALCIUM WITH OXYGEN forms

CALCIUM OXIDE. LIME, CaO.

Description.—A white caustic infusible substance giving an intense white light in the oxyhydrogen flame.

Preparation.—(1) By heating limestone (the carbonate) $CaCO_3$ in kilns by the aid of coal mixed with the stone. Carbonic anhydride (CO_2) escapes, and quick or caustic lime remains.

(2) By heating carbonate of lime ($CaCO_3$) to redness. Thus—

$$CaCO_3 + \text{heat} = CO_2 + CaO.$$

Lime combines very readily with H_2O, giving out great heat, and precipitating a white powder called *slaked lime* (CaH_2O_2) or calcium hydroxide. This is slightly soluble in water, one part dissolving in 730 parts of cold, but only in 1,300 of boiling water, and forming *lime-water*, which has a great power of absorbing carbonic acid from the air. *Mortar* is a mixture of slaked lime, water and sand, the lime gradually combining with the silica. *Hydraulic mortars* harden under water, and are prepared by heating impure lime containing clay and silica; silicate of lime and alumina form upon moistening the powder, which then sets to a solid, and is unaffected by water. Lime is used in agriculture,

(1) To destroy excess of vegetable matter in the soil.

(2) To liberate potash for the use of plants by decomposing the silicate in heavy clay soils.

CALCIUM CARBONATE, $CaCO_3$,

Occurs widely diffused as chalk, limestone, coral and marble; also crystalline as Iceland spar (rhombohedral), and as arragonite (rhombic); this substance is therefore polymorphous or crystallising in different systems.

$CaCO_3$ is almost insoluble in *pure* water, but if the water contain carbonic acid it readily dissolves, causing *temporarily hard water.* Upon boiling the water the carbonic acid is given off, and thus a crust of $CaCO_3$ is deposited. The formation of this crust may be obviated by the addition of sal-ammoniac (NH_4Cl) to the water. Thus—

$$CaCO_3 + 2NH_4Cl = CaCl_2 + (NH_4)_2CO_3.$$

Chloride of calcium and carbonate of ammonia are produced.

Water may be softened by suspending sufficient lime to neutralise the excess of CO_2 in the water hardened by the dissolved carbonate.

CALCIUM SULPHATE, $CaSO_4$.

Occurs as a mineral *Anhydrite* and combined with $2H_2O$ as *gypsum* and *alabaster*. It is soluble in 400 parts of water, and forms a common impurity of spring water, causing *permanent hardness*, since boiling will not remove it. *Plaster of Paris* is formed by the application of moderate heat to gypsum which by this means loses its $2H_2O$, and upon again moistening, the $2H_2O$ is again taken up, and the substance sets to a solid mass.

CHLORIDE OF CALCIUM, $CaCl_2$.

A soluble salt formed from limestone or marble ($CaCO_3$) by the addition of hydrochloric acid (HCl). Thus—

$$CaCO_3 + 2HCl = CO_2 + H_2O + CaCl_2.$$

Carbonic anhydride, water, and chloride of calcium are formed.

Upon evaporating the solution, colourless, needle-shaped crystals of $CaCl_2 + 6H_2O$, the hydrated chloride, are formed. Upon drying, this substance forms a porous mass which absorbs water very greedily, and is used for drying gases.

BLEACHING POWDER, OR CHLORIDE OF LIME.

$CaCl_2$, $Ca2ClO$ or $Ca\left\{\begin{matrix}Cl\\OCl\end{matrix}\right.$ has been described earlier under the head of Chlorine. Other compounds of calcium are

Calcium Fluoride, or Fluor Spar, CaF_2.
Calcium Phosphate, $Ca_3P_2O_8$.
Calcium Sulphide, CaS.
Calcium Pentasulphide, CaS_5.

Tests for the Calcium Compounds—

(1) The spectrum of calcium contains a number of bright lines of which a green line and an orange line at about an equal distance on each side of the sodium line are the most characteristic.

(2) Any salt of calcium held on platinum wire in a Bunsen burner flame acquires a bright orange tint.

(3) Oxalate of ammonium gives a white precipitate of oxalate of lime. This is a very delicate test, since by it the $\frac{1}{10,000}$ of a grain of calcium may be detected.

STRONTIUM—(Strontian, a village in Scotland).

Symbol, Sr. Combining weight, 87·5. Specific gravity, 2·54.

Description.—A pale yellow metal, found only in a few mineral deposits, especially as the carbonate (Strontianite) and the sulphate (Celestine). It occurs also in small quantities in certain spring waters, and closely resembles calcium in its properties.

Preparation.—By passing a current of electricity through the fused chloride ($SrCl_2$).

When heated in the air strontium forms

STRONTIUM MONOXIDE, SrO. STRONTIA.

Description and Preparation.—A white substance obtained by decomposing the nitrate of strontia, ($Sr2NO_3$) by heat. With water it evolves great heat, forming the *hydrate*, ($SrO + 9H_2O$), which is soluble in water and greedily absorbs carbonic anhydride.

The carbonate and sulphate of strontia are insoluble in water, and are employed in the preparation of the other salts of this metal. The nitrate of strontia ($Sr2NO_3$), and the chloride ($SrCl_2$) are soluble in water, and are the only salts used in the arts, in which they are employed in preparing *Red Fires.* "Red Fire" is composed of a mixture of 40 parts of $Sr2NO_3$, 10 of chlorate of potash ($KClO_3$), 13 of sulphur (S), and 4 of tri-sulphide of antimony (Sb_2S_3).

Tests for the Strontium Compounds—

(1) The salts of strontium tinge flame carmine-red.

(2) The spectrum shows five or six lines in the red, and (if with the high temperature of the blow-pipe flame) one line in the blue.

(3) Hydrofluosilicic acid gives no precipitate. (*See* Barium tests).

(4) Sulphuric acid gives a white precipitate of sulphate of strontia, nearly as insoluble as sulphate of baryta.

BARIUM—(Barus, heavy).

Symbol, Ba. Combining weight, 137. Specific gravity, 1·5.

Description and Sources.—A metallic powder of a pale yellow colour, closely resembling calcium and strontium in its properties. The most common minerals in which barium occurs are the sulphate, *heavy spar*, and the carbonate or *Witherite.*

Preparation.—By passing a current of electricity through the fused chloride ($BaCl_2$).

BARIUM WITH OXYGEN forms two oxides—

(1) Barium monoxide or baryta, BaO.
(2) Barium dioxide, BaO_2.

BARYTA, BaO,

Is a grey substance, prepared by decomposing the nitrate ($Ba2NO_3$) by heat. It fuses at a high temperature, takes up water with the evolution of great heat and the formation of a crystalline hydrate ($BaH_2O_2 + 8H_2O$). This hydrate is soluble in twenty parts of cold water, and by exposure to air the solution absorbs carbonic anhydride and becomes milky.

BARIUM DIOXIDE, BaO_2.

A grey substance formed by gently heating baryta in a current of oxygen. It is used for preparing hydrogen dioxide (H_2O_2).

BARIUM CHLORIDE, $BaCl_2$.

A soluble salt, and one of the most important salts of barium. May be prepared from barium carbonate ($BaCO_3$) and hydrochloric acid (HCl). Thus—

$$BaCO_3 + 2HCl = CO_2 + H_2O + BaCl_2.$$

It is much used as a precipitant of sulphuric acid.

BARIUM SULPHATE, $BaSO_4$,

Occurs native as *heavy spar.* Specific gravity, 4·6. Is one of the most insoluble salts known, and may be prepared from a soluble salt of barium by the addition of sulphuric acid. Thus—

$$BaCl_2 + H_2SO_4 = 2HCl + BaSO_4.$$

Hydrochloric acid and sulphate of baryta are formed.

It is employed as a paint, termed *blanc-fixe,* when precipitated, and the native *heavy spar,* when ground, is largely used as an adulterant for white lead.

Other salts of barium are the nitrate ($Ba2NO_3$), a soluble salt; the sulphide (BaS) (obtained by heating $BaSO_4$ with coal), decomposing when added to water into barium hydroxide BaH_2O_2, and hydrosulphide of barium BaH_2S_2, both soluble.

The carbonate ($BaCO_3$), barium silico-fluoride (BaF_2SiF_4), and the phosphate ($Ba_3P_2O_8$) are insoluble. The soluble salts of barium are poisonous.

Tests for the Barium Compounds—

(1) The salts of barium tinge flame green.

(2) The spectrum shows a series of bright bands in the green, and fainter bands in the red.

(3) Hydrofluosilicic acid gives a white precipitate with barium, but none with strontium and calcium.

General Characteristics of the Metals of the Alkaline Earths.

These metals are all dyads. They are irreducible by carbon or hydrogen alone. They are capable of decomposing water at all temperatures, with the production of oxides, which in combination with water form hydroxides; and from some of these it is possible to drive off the water by heat. Their carbonates are insoluble in water. Carbonates of lime and magnesia may be readily rendered soluble if the water contains excess of carbonic acid.

GROUP III.—THE METALS OF THE EARTHS.

There are no less than six of these, but the only one of importance is the following, viz.:

ALUMINIUM.

Symbol, Al. Combining weight, 27·4. Specific gravity, 2·6.

Description.—A silver-white metal, unaffected by air, extremely light, and consequently much employed for the manufacture of optical instruments.

Aluminium is a triad element, and decomposes water at a very high temperature.

Sources.—Found combined with oxygen and silicon in large quantities in the older rocks, in felspar (a compound of silicon, potassium, aluminium and oxygen, Si_3AlKO_8), in clay (silicate of aluminium), and in many crystalline minerals.

Preparation.—By passing the vapour of chloride of aluminium (Al_2Cl_6) over metallic sodium (Na). Thus—

$$Al_2Cl_6 + 6Na = 6NaCl + 2Al.$$

Common salt and aluminium are formed.

ALUMINIUM CHLORIDE, Al_2Cl_6,

Is a transparent, waxy, colourless substance, with crystalline structure, prepared by heating alumina (Al_2O_3) and charcoal (C) in a current of chlorine (Cl). Thus—

$$Al_2O_3 + 3C + 6Cl = 3CO + Al_2Cl_6.$$

Carbonic oxide and aluminium chloride are formed.

ALUMINIUM SULPHATE, $Al_2(SO_4)_3$.

Occurs in soluble thin pearly plates, with sweet astringent taste and acid reaction. It is prepared by the action of sulphuric acid upon clay.

ALUMEN—ALUM, $NH_4Al(SO_4)_2 + 12H_2O$.

This substance is a double sulphate of alumina and ammonia. It is prepared by roasting alum-schist, which contains sulphide of aluminium. By the roasting and exposure to air the sulphide becomes sulphate, and thus sulphate of alumina is formed. A solution of sulphate of ammonia is now added, and the whole crystallises out as alum.

ISOMORPHISM—(*isos* equal, *morphe* form).

Those bodies are said to be *isomorphous* which crystallise in the same form, but differ in their chemical and physical properties. Alum may be taken as a type of these substances, since the ammonium may be replaced by any other alkaline metal. Thus—

$NH_4Al(SO_4)_2 + 12H_2O$ = Ammonia Alum.
$Na\ Al(SO_4)_2 + 12H_2O$ = Soda Alum.
$Li\ Al(SO_4)_2 + 12H_2O$ = Lithia Alum.
$K\ Al(SO_4)_2 + 12H_2O$ = Potash Alum.

Again, the sesquioxide of aluminium (Al_2O_3) may be replaced by the isomorphous sesquioxides of iron (Fe_2O_3), of chromium (Cr_2O_3), and of manganese (Mn_2O_3). Thus—

$NH_4Al(SO_4)_2 + 12H_2O$ = Alumina Alum.
$NH_4Fe(SO_4)_2 + 12H_2O$ = Iron Alum.
$NH_4Cr(SO_4)_2 + 12H_2O$ = Chromium Alum.
$NH_4Mn(SO_4)_2 + 12H_2O$ = Manganese Alum.

It may here be explained that after stating that the sesquioxides are substituted, we find Al, Fe, Cr, Mn, in the formulæ, but it must be remembered that alum is really composed of $(NH_4)_2SO_4$ (sulphate of ammonia), and $Al_2(SO_4)_3$ (sulphate of alumina), and the original formula for this alum would be $(NH_4)_2Al_2(SO_4)_4 + 24H_2O$, but to simplify the equation we divide by 2 and obtain $NH_4Al(SO_4)_2 + 12H_2O$.

ALUMINIUM WITH OXYGEN FORMS ALUMINA.

Symbol, Al_2O_3. Specific gravity, 3·9.

The only known oxide, occurring native in the ruby and sapphire. Is attacked with difficulty by acids, but the hydrate ($Al_2O_3,3H_2O$) is easily dissolved by acids and by fixed caustic alkalies. It is largely used in dyeing as a mordant, since it forms "*lakes*" (insoluble compounds) with vegetable colouring matter, producing the so-called *fast* colours. By adding ammonia to a solution of alum, the hydroxide ($Al_2O_3,3H_2O$) falls down as a white precipitate, and this, upon heating, yields pure alumina as a white amorphous powder.

Tests for the Aluminium Compounds—

(1) The caustic alkalies give white precipitates, soluble in excess.

(2) Ammonia gives a white precipitate insoluble in excess.

(3) Any salt of aluminium, with a solution of cobalt, acquires an *ultramarine blue* colour before the blow-pipe.

Glass.

This is a compound produced by fusing the silicates with the alkaline metals. There are four varieties, viz. :

(1) *Crown, window, and plate-glass*, containing sodium and calcium silicates.

(2) *Bohemian glass*, containing potassium and calcium silicates.

(3) *Flint glass, or crystal*, containing potassium and lead silicates.

(4) *Common green bottle-glass*, containing sodium, calcium, iron, and aluminium silicates.

The addition of oxide of lead increases the lustre of the glass, as well as its fusibility and specific gravity.

Coloured Glasses.

Ferrous oxide (FeO) produces a deep green (bottle glass), and manganese oxide communicates a purple tint to glass. It is difficult to obtain materials entirely free from iron, which gives a green tinge; in order therefore, to obtain a colourless glass, a small portion of manganese dioxide (MnO_2) is added, and the violet colour thus formed being complementary to the green, a nearly colourless glass is produced. Arsenious anhydride (As_2O_3) will ensure the same end by converting the ferrous into ferric-oxide. "Paste" is a brilliant lead glass, and upon the addition of certain oxides to this the colours of precious stones may be imitated. The blue of the sapphire is yielded by cobalt oxide; a ruby-red by cuprous oxide, whilst the yellow of the topaz is imparted by ferric oxide.

GROUP IV.—THE ZINC GROUP.

MAGNESIUM. ZINC. CADMIUM.

MAGNESIUM—(Magnesia, a town in Asia Minor).

Symbol, Mg. Combining weight, 24·0. Specific gravity, 1·74.

Description.—A white, ductile, malleable metal, which fuses at a low red heat, and when soft may be pressed into wire. When strongly heated in the air it ignites and burns with a dazzling white light, forming magnesia (MgO), the oxide. So rich is this light in chemically active rays, that it has been used as a substitute for sunlight, and has been made available for photographing the interior of the pyramids. This metal rapidly dissolves in sulphuric and hydrochloric acids, evolving hydrogen.

Sources.—Found in large quantities as the carbonate or *dolomite* in mountain limestone, combined with calcium carbonate; also in certain mineral springs as sulphate and chloride, and in sea-water.

Preparation.—By heating magnesium chloride ($MgCl_2$) with metallic sodium (Na). Thus—

$$MgCl_2 + 2Na = 2NaCl + Mg.$$

Common salt and magnesium are formed.

MAGNESIA, MgO.

A soft, white, insoluble powder, known in medicine as calcined magnesia. It unites with acids to form the magnesium salts, and is prepared by heating the nitrate or carbonate.

MAGNESIUM CHLORIDE, $MgCl_2$.

A white, crystalline, deliquescent, fusible salt, prepared by the addition of hydrochloric acid (HCl) to magnesium carbonate ($MgCO_3$.) Thus—

$$MgCO_3 + 2HCl = H_2CO_3 + MgCl_2.$$

Carbonic acid and magnesium chloride are formed.

MAGNESIUM SULPHATE, $MgSO_4 + 7H_2O$.

A soluble substance, known as Epsom Salts, occurring in right rhombic prisms. This salt forms with the alkaline sulphates, double salts in which the alkaline sulphate supplies the place of one molecule of water of crystallisation. Thus—

$$MgSO_4, K_2SO_4 + 6H_2O.$$

Preparation.—By the addition of sulphuric acid (H_2SO_4) to dolomite ($CaCO_3,MgCO_3$). Thus—

$$CaCO_3, MgCO_3 + 2H_2SO_4 = CaSO_4 + 2CO_2 + 2H_2O + MgSO_4.$$

Sulphate of lime, carbonic anhydride, water, and magnesium sulphate result.

MAGNESIUM CARBONATE, $MgCO_3$.

An insoluble compound, occurring as a mineral termed *magnesite.* "Magnesia alba" consists of a varying mixture of carbonate and hydrate of magnesia ($MgCO_3MgH_2O_2 + 6H_2O$).

Tests for the Magnesium Compounds—

(1) Any phosphate with a little ammonia gives a white precipitate of ammonio-magnesian phosphate, soluble in acids.

(2) The salts are white, but when heated before the blowpipe with nitrate of cobalt acquire a pink tinge.

ZINC.

Symbol, Zn. Combining weight, 65·2. Specific gravity, 6·8 to 7·2.

Description.—A blueish white metal, crystalline when broken transversely, and brittle at the ordinary temperature; when heated to 130° C. it may be hammered easily, but if more strongly heated to 200° C. it again becomes brittle.

Zinc melts at 423° C. and boils at a bright red heat; should air be present, it ignites and burns with a luminous green flame, forming the oxide ZnO. Since neither moist nor dry air act upon zinc, this metal is used in the form of sheets as a protecting covering for iron, which latter metal is then said to be *galvanized.* One part of zinc and two of copper form brass, and an alloy of zinc, nickel and copper forms German silver.

Sources.—The chief ores of zinc are the sulphide *Blende*, and the carbonate *Calamine.*

Preparation.—The powdered ore (carbonate or sulphide) is roasted in order to convert it into oxide. Fine coal is then mixed with the roasted ore, and strongly heated in crucibles of a peculiar shape. Carbon monoxide is given off, and the metallic zinc distills over and is condensed.

ZINC OXIDE, ZnO.

The only known compound of zinc with oxygen. It is an insoluble white amorphous powder, becoming yellow on heating, but losing that colour on cooling. It is used as a pigment, termed zinc white.

It is prepared by (1) precipitating a soluble zinc salt with an alkali, or (2) by heating the carbonate. Thus—

$$ZnCO_3 + \text{heat} = CO_2 + ZnO.$$

Carbonic anhydride and zinc oxide are formed.

ZINC SULPHATE, $ZnSO_4 + 7H_2O$.

Is called "white vitriol," and crystallises in long prisms. It is prepared by the action of sulphuric acid upon zinc. Thus—

$$Zn + H_2SO_4 = 2H + ZnSO_4.$$

Hydrogen is evolved, and sulphate of zinc is formed.

ZINC CHLORIDE, $ZnCl_2$.

A white, fusible, deliquescent substance, prepared by the action of hydrochloric acid upon zinc. Thus—

$$Zn + 2HCl = 2H + ZnCl_2.$$

Hydrogen and zinc chloride result.

ZINC SULPHIDE, ZnS,

Occurs as a mineral called *Blende.* It is formed when an alkaline sulphide is added to a soluble salt of zinc.

ZINC CARBONATE, $ZnCO_3$.

An insoluble substance, occurring native as *Calamine.* May be prepared from sulphate of zinc ($ZnSO_4$), and carbonate of soda (Na_2CO_3). Thus—

$$ZnSO_4 + Na_2CO_3 = Na_2SO_4 + ZnCO_3.$$

Sulphate of soda and zinc carbonate are formed.

Tests for the Zinc Compounds—

(1) Sulphuretted hydrogen gives a *white* precipitate in neutral solutions; none in acid solutions.

(2) Ferrocyanide of potassium gives a white precipitate.

(3) Sodium carbonate, charcoal, and the blow-pipe give yellow (ZnO), which becomes white on cooling; the latter, heated with cobalt nitrate in the outer flame of the blow-pipe, acquires a fine green colour.

CADMIUM.

Symbol, Cd. Combining weight, 112. Specific gravity, 8·6.

A comparatively rare metal, occurring in small quantities in most zinc ores. It closely resembles zinc, but is more volatile, and distils over first in the preparation of that metal.

Cadmium is a white ductile metal which melts at 315° C. It takes fire when heated in the air, forming CdO, the brown oxide. The iodide of cadmium is sometimes used in photography, and the yellow sulphide has been used as a pigment.

Test for the Cadmium Compounds—

Sulphuretted hydrogen gives a yellow precipitate insoluble in alkalies.

General Characteristics of the Zinc Group.

All these metals are dyads, are all volatile at high temperatures, and burn when heated in the air. They each form only one oxide and one chloride, and decompose water at a high temperature.

GROUP V.—THE IRON GROUP.

MANGANESE.	IRON.	COBALT.
NICKEL.	CHROMIUM.	

MANGANESIUM.

Symbol, Mn. Combining weight, 55. Specific gravity, 8·0.

Description.—A reddish, lustrous, brittle metal, hard enough to scratch glass. Decomposes water at ordinary temperatures, with evolution of hydrogen. Must be kept under naphtha, as it rapidly undergoes oxidation in air. An alloy of manganese and iron is much employed in the manufacture of steel. Occurs in nature as the black and red oxide.

Preparation.—Is obtained, but with difficulty, by heating the oxide very strongly with charcoal.

The compounds of manganese with oxygen are five in number, viz.:

(1) *Manganous oxide or manganous monoxide,*	MnO.
(2) *Manganic oxide or manganese sesquioxide,*	Mn_2O_3.
(3) *Mangano-manganic oxide or red oxide,*	Mn_3O_4.
(4) *Manganese dioxide or black oxide,*	MnO_2.
(5) *Manganese heptoxide,*	Mn_2O_7.

MANGANESE MONOXIDE, MnO.

A green powder, prepared by passing hydrogen gas (H) over the heated carbonate ($MnCO_3$). Thus—

$$MnCO_3 + 2H = CO + H_2O + MnO.$$

Carbonic oxide, water, and manganese monoxide are formed.

This substance forms with acids the pink-coloured salts.

The chief soluble manganous salts are the *sulphate* $MnSO_4 + 5H_2O$, and the *chloride* $MnCl_2 + 4H_2O$.

The chief insoluble manganous compounds are the flesh-coloured *sulphide* MnS, and the *carbonate* $MnCO_3$, a white powder.

MANGANIC OXIDE, Mn_2O_3,

Occurs in nature as a mineral *Braunite.* It forms salts of somewhat unstable nature, the most important being the manganese alum, in which the Al_2O_3 of the common alum is replaced by Mn_2O_3.

MANGANO-MANGANIC OXIDE, Mn_3O_4,

Is a neutral body, occurring native as *Hausmannite,* and corresponding to the magnetic oxide of iron.

MANGANESE DIOXIDE, MnO_2,

Occurs in the minerals *Pyrolusite* and *Varvacite,* and is the common black ore of manganese. It is much used for the preparation of oxygen and chlorine.

MANGANESE HEPTOXIDE, Mn_2O_7,

Is a dark green heavy liquid, prepared by the addition of strong cold sulphuric acid (H_2SO_4) to permanganate of potassium. This salt is easily decomposed by heat, with the evolution of oxygen which is rich in ozone.

MANGANIC AND PERMANGANIC ACIDS.

These acids have never been isolated, but they are known in composition, for should a caustic alkali, such as caustic potash (KHO), be fused with an oxide of manganese, a *bright green mass* is formed, and this, with water, will yield a dark green solution containing *potassium manganate* (K_2MnO_4). Upon standing, this dark green solution changes to a bright purple, and deposits the hydrated manganese dioxide. A new salt is now contained, viz. : *potassium permanganate* ($KMnO_4$). The following are therefore the theoretical formulæ :

Manganic acid H_2MnO_4.
Permanganic acid $HMnO_4$.

Tests for the Manganesium Compounds :

(1) The alkalies give *white* precipitates, becoming *brown.*

(2) Sulphide of ammonium (NH_4HS) gives a *flesh-coloured* sulphide.

(3) With borax bead before the blow-pipe, the salts form an amethyst-red in the outer flame, and a colourless one in the inner.

(4) These salts, when heated upon platinum foil with carbonate of soda (Na_2CO_3), yield a *bluish-green opaque bead* of sodium manganate (Na_2MnO_4).

FERRUM—IRON.

Symbol, Fe. Combining weight, 56. Specific gravity, 7·8.

Description.—A bright, white metal, exceedingly tough, although soft. Pure metallic iron is found only in very small quantity, and almost alone composing the "Meteoric stones," which are supposed to be of extra-terrestrial origin. The chief ores of this metal are the iron-pyrites (FeS_2), the magnetic oxide (Fe_3O_4), red-hæmatite and Elba-iron (Fe_2O_3), and the carbonate, or clay-ironstone.

In commerce, iron exists in three forms, viz.:

(1) Wrought iron (nearly pure iron).

(2) Cast iron (iron with varying quantities of carbon and silicon).

(3) Steel (iron with less carbon than that needed to form the cast variety).

Pure iron, as powder, may be prepared by moderately heating the oxide in a current of hydrogen gas, and since, when exposed to the air, finely divided iron takes fire, it is necessary to retain it in an atmosphere of hydrogen.

After being uniformly hammered and broken, this metal presents a *crystalline granular* structure, which becomes *fibrous* when rolled into bars, and this fibrous texture, after long-continued vibration, returns to the original crystalline state; hence the accidents that have taken place from the snapping of railway axles.

Some of the compounds and the metal itself are highly magnetic, losing this property when red-hot, and receiving it again on cooling.

Iron in a solid mass will not tarnish in dry air, but when heated it oxidizes in black scales of oxide, and if more strongly heated it takes fire, forming the same black oxide. In water containing a trace of carbonic acid, iron gradually becomes coated with *rust* ($Fe_2O_33H_2O$), but in pure water the metal remains unchanged.

IRON MANUFACTURE.

Wrought-iron was at one time manufactured by reducing it from its ore by heating it with coal in a wind furnac and hammering out the resulting spongy mass.

The present method consists in first forming *cast-iron*, and separating out subsequently the carbon and silicon which it contains. The chief source of this cast iron is the clay-ironstone (ferrous carbonate ($FeCO_3$) united with silicate of alumina or clay). This is first submitted to roasting, by which process the carbonic acid is driven off and the ferric oxide formed, the ore being then thrown with coal and limestone into a *blast furnace*, the construction of which is as follows:

THE BLAST FURNACE

Consists of a double cone of strong fire-brick, about 50 feet in height, and from 15 to 18 feet wide at the broadest part. It is closed at the bottom, air being blown in near that part in a powerful blast by means of tuyeres or pipes. The fuel and ore are thrown in at the top, the burning mass sinking down, and the molten mass being drawn off at the bottom. At the lowest part is the hearth, where the melted metal and fused slag collect; the latter, which swims upon the surface of the metal, runs continuously from an aperture in the upper part of the hearth, and the former is from time to time tapped from the bottom of the hearth and cast into pigs (as they are called) in moulds made in the sand. The ferric oxide, in passing from the top to the bottom of the furnace, is first reduced to porous metallic iron by the carbonic oxide gas generated from the burning coal; then, meeting with the clay and lime-stone in a hotter part of the furnace, a slag or fusible silicate is formed, and the heated metal encountering carbon, unites with this to form cast-iron in a fusible form, the silica of which in the hottest part of the furnace is reduced to silicon, and thus cast-iron is formed.

Cast-iron is not a definite chemical compound of carbon and silicon with iron, since the carbon may exist in it as scales of graphite, occasioning the *mottled cast-iron*, or in combination as *white cast-iron*. Sulphur and phosphorus are sometimes found in cast-iron, but these must be looked upon as impurities.

Wrought-iron is obtained from cast-iron by the process of "refining" and "puddling." Here the carbon, silicon, phosphorus and sulphur are burnt out by exposing the heated metal to a current of air in a reverberatory furnace, a coat of oxide gradually accumulating upon the melted cast-iron, which is then rolled into balls. The whole of the carbon passes off as carbonic oxide, the silicon being oxidized to silica, which forms a fusible slag by uniting with the oxide of iron; the phosphorus and sulphur also undergo oxidation. The liquid slag is squeezed out of the balls by hammering, and the mass finally rolled into plates or bars.

Although wrought-iron melts only at a very high temperature and with great difficulty, it becomes soft at a much lower one, and when hot possesses the property of "welding," *i.e.*, two clean surfaces of hot metal when hammered together uniting firmly.

Steel is formed by heating bars of wrought-iron to redness in contact with charcoal; it is then found that the bar, instead of being fibrous, has become fine-grained; it is at the same time more flexible, and capable of taking a fine edge, is more fusible, and contains from one to two per cent. of carbon.

THE BESSEMER PROCESS

Consists in burning away the whole of the silicon in cast-iron by means of a blast of air through the molten metal, and then adding sufficient pure cast-iron to yield enough carbon to convert the whole into steel.

Iron is a tetrad element, and forms the following oxides. With all tetrads it will be observed that the formulæ are usually written with half their molecular weight. Thus—

Ferrous oxide ... ... FeO.
Ferric oxide ... ... Fe_2O_3.
Black, or Magnetic oxide ... ... Fe_3O_4.

FERROUS OXIDE, FeO,

Has never been prepared pure, since it greedily absorbs oxygen, and forms higher oxides. It may be prepared as a white precipitate in total absence of oxygen, by precipitating a soluble ferrous salt by means of caustic alkali. If oxygen be present, a greenish precipitate is formed. With this oxide the ferrous salts are formed, the most important of which are—

FERROUS SULPHATE—PROTOSULPHATE OF IRON, $FeSO_4 + 7H_2O$,

Commonly called *green vitriol*, or copperas. May be prepared (1) by the addition of sulphuric acid (H_2SO_4) to metallic iron (Fe). Thus—

$$Fe + H_2SO_4 = H_2 + FeSO_4.$$

Hydrogen and ferrous sulphate being formed; or (2) by slowly oxidising metallic iron (Fe) with iron pyrites (FeS_2). Thus—

$$FeS_2 + Fe + 8O = 2FeSO_4.$$

FERROUS CHLORIDE, $FeCl_2$,

May be prepared by passing dry hydrochloric acid gas (HCl) over hot metallic iron (Fe). Thus—

$$Fe + 2HCl = 2H + FeCl_2.$$

Hydrogen escaping and ferrous chloride being formed.

FERROUS CARBONATE, $FeCO_3$,

Occurs as a mineral, called spathose-iron-ore, and less pure in clay ironstone.

FERROUS SULPHIDE, FeS,

Is a black substance, obtained by fusing together equivalent quantities of iron and sulphur. The disulphide FeS_2 is found in large quantities.

All the ferrous compounds are readily prone to oxidation, passing into the ferric salts.

FERRIC OXIDE, Fe_2O_3,

Sometimes called iron sesquioxide, occurs native as red-hæmatite, and specular-iron-ore; with water it forms brown hæmatite. May be prepared (1) by heating ferrous sulphate to redness, or (2) by adding liquor ammoniæ (NH_4HO) to a solution of ferric chloride (Fe_2Cl_6). Thus—

$$Fe_2Cl_6 + 6NH_4HO = 6NH_4Cl + 3H_2O + Fe_2O_3.$$

Chloride of ammonium, water, and ferric oxide are formed.

With this oxide the ferric-salts are formed, the most important of which are the following—

FERRIC CHLORIDE, Fe_2Cl_6.

Obtained in anhydrous brilliant red crystals; by (1) passing chlorine gas over hot metallic iron, or in a hydrated form; by (2) acting upon ferrous chloride ($FeCl_2$) with a mixture of hydrochloric acid (HCl), and nitric acid (HNO_3). Thus—

$$6FeCl_2 + 6HCl + 2HNO_3 = N_2O_2 + 4H_2O + 3Fe_2Cl_6.$$

Nitric oxide, water, and ferric chloride result.

By passing sulphuretted hydrogen (H_2S) through Fe_2Cl_6, a white precipitate of sulphur is produced, together with hydrochloric acid and ferrous chloride. Thus—

$$Fe_2Cl_6 + H_2S = S + 2HCl + 2FeCl_2.$$

FERRIC SULPHATE, $Fe_2(SO_4)_3$,

Is obtained as a buff-coloured amorphous mass by acting upon ferrous sulphate ($FeSO_4$) with a mixture of sulphuric acid (H_2SO_4), and nitric acid (HNO_3). Thus—

$$6FeSO_4 + 3H_2SO_4 + 2HNO_3 = 4H_2O + N_2O_2 + 3Fe_2(SO_4)_3.$$

THE MAGNETIC OR BLACK OXIDE, Fe_3O_4,

Occurs native as the mineral *lode-stone*, sometimes called *erroso-ferric oxide*. It is formed when iron is oxidised at a high temperature in aqueous vapour, air, or oxygen.

FERRIC ACID, H_2FeO_4, ?

Is only known in combination. By fusing together nitrate of potash (KNO_3), and ferric oxide (Fe_2O_3), and placing the result in ice-cold water, a deep amethyst-coloured solution is produced, which contains *potassium ferrate* (K_2FeO_4).

Tests for the Iron Compounds—

For the *Ferrous* salts:

These are of a *light green* colour, and in solution give—

(1) With alkalies, a white precipitate turning *greenish-brown*.

(2) With ferrocyanide of potassium (K_4FeCy_6), a white precipitate passing through *light blue* to dark blue.

(3) With ferricyanide of potassium (K_3FeCy_6), a *dark blue* precipitate.

(4) With sulphuretted hydrogen (H_2S), no precipitate.

(5) With sulphide of ammonium (NH_4HS), a black precipitate.

(6) With sulphocyanide of potassium (KSCy), no precipitate.

(7) With tincture of galls, no precipitate.

For the *Ferric* salts:

These are of a *reddish-brown* colour, and in solution give—

(1) With alkalies, a *foxy-red* precipitate.

(2) With K_4FeCy_6, a *Prussian blue* precipitate.

(3) With K_3FeCy_6, no special precipitate, but usually a green colour.

(4) With H_2S, a precipitate of sulphur (white), and the ferric salts are converted into the ferrous.

(5) With KSCy, a *blood-red* precipitate.

(6) With tincture of galls, a bluish-black precipitate.

COBALT.

Symbol, Co. Combining weight, 58·7. Specific gravity, 8·5.

Description.—A reddish-white, very tenacious metal, strongly magnetic and infusible. Does not occur native, but is found combined with sulphur and arsenic as tin-white cobalt ($CoAs_2$) and cobalt-glance ($CoAsS$). The cobalt compounds are characterised by their brilliancy of colour; they give a splendid blue tint to glass, and are used as pigments. There are three oxides of cobalt—

(1) The monoxide	CoO.
(2) The sesquioxide	Co_2O_3
(3) An oxide	Co_3O_4.

The monoxide, with acids, forms a series of salts which when hydrated are pink, and when anhydrous are blue. The sesquioxide forms no salts.

There are two series of salts, the Cobaltous and Cobaltic.

Tests—

For the *Cobaltous* salts:

(1) Liquor potassæ gives a blue precipitate turning red.
(2) Liquor ammoniæ gives a blue, turning brown.
(3) Ferrocyanide of potassium gives a greyish-green.
(4) Sulphide of ammonium gives a black.
(5) Carbonate of ammonia gives a pink.

For the *Cobaltic* salts:

(1) Liquor potassæ gives a dark-brown.
(2) Liquor ammoniæ gives a brownish-red.
(3) Sulphide of ammonium gives a black.
(4) Carbonate of ammonia gives a green.

Cobalt salts with the borax bead on platinum wire yield a very characteristic blue bead.

NICKEL.

Symbol, Ni. Combining weight, 58·7. Specific gravity, 8·8.

Description.—A white, tenacious metal, strongly magnetic, but losing this property when heated to 350°C.

There are two oxides of nickel—

(1) The monoxide	NiO.
(2) The sesquioxide	Ni_2O_3.

The monoxide gives rise to those nickel salts which possess a green colour.

Tests—

(1) Alkalies, ammonia, and carbonates give a pale apple-green precipitate.
(2) Ferrocyanide of potassium gives a green precipitate.
(3) Sulphide of ammonium gives a black precipitate.

CHROMIUM—(*Chroma*, colour).

Symbol, Cr. Combining weight, 52·2. Specific gravity, 6·8.

Description.—The chief ore of chromium is the chrome ironstone $FeOCr_2O_3$.

The compounds of chromium are chiefly used in the arts as pigments, since many of them possess fine bright colours. The green of porcelain is communicated by the sesquioxide (Cr_2O_3). Chromium is the most infusible of all the metals, but it has been obtained by another process in the form of bright crystals.

There are four compounds of chromium with oxygen, viz.:

(1)	Chromium monoxide	CrO.
(2)	Chromium sesquioxide	Cr_2O_3.
(3)	Chromo-chromic oxide	$CrOCr_2O_3$.
(4)	Chromium trioxide	CrO_3.

The two first oxides are basic, and form corresponding salts.

The third oxide corresponds to the magnetic oxide of iron, and chromium trioxide forms an acid with water—chromic acid (H_2CrO_4)—which neutralises bases forming red or yellow coloured chromates.

There are three potassium chromates known, viz.:

(1)	Neutral potassium chromate ...	K_2CrO_4.
(2)	Potassium anhydro-chromate, or bichromate	$K_2CrO_4CrO_3$
(3)	Potassium dianhydrochromate or terchromate	$K_2CrO_42CrO_3$.

Other salts of Chromium are the Chromic chloride, Cr_2Cl_6, the chromic sulphate, $Cr_2(SO_4)_3$, both insoluble salts. The insoluble chromates are lead chromate, $PbCrO_4$, or chrome yellow; silver chromate, Ag_2CrO_4, a deep-red coloured salt, and barium chromate, $BaCrO_4$, a yellow insoluble powder. Chloro-chromic oxide, CrO_2Cl_2 is a volatile compound, intermediate between chrome trioxide and chromic chloride, and is a dark-red, strongly fuming liquid.

Tests for the Chromium Compounds—

For the *Chromous* salts:

(1) Sulphide of ammonium gives a black precipitate.

(2) Liquor ammoniæ gives a blue precipitate, turning green.

(3) Tungstic acid gives a blue precipitate.

For the *Chromic* salts:

(1) Sulphide of ammonium gives a greyish-green precipitate.

(2) Liquor ammoniæ gives a greyish-green precipitate.

(3) Barium salts give pale yellow precipitates.

(4) Lead salts give bright yellow precipitates.
(5) Mercurous salts give brick-red precipitates.
(6) Silver salts give crimson precipitates.

All the salts of chromium yield with borax and the blowpipe an emerald-green glass in the reducing flame.

General Characteristics of the Iron Group.

These metals arc all dyads, except iron, which is a tetrad. They decompose water, like the preceding class, form several oxides, chlorides, and sulphides, and are not volatile at the temperature of our furnaces.

GROUP VI.—THE TIN GROUP.

Although several metals belong to this group, tin is the only one employed in the arts, and is therefore the only one that will be here described.

STANNUM (Stan, *Saxon*, a stone)—TIN.

Symbol, Sn. Combining weight, 118. Specific gravity, 7·3.

Description.—A white metal, like silver, soft, and malleable, but possessing no tenacity. Emits a peculiar crackling when bent. Tin melts at 235°C., and does not lose its lustre on exposure to air, but when strongly heated it takes fire, a white powder (stannic oxide), or "putty powder," being formed. Tin is a tetrad.

Sources.—Metallic tin is not found native, and the tin ores are found only in a few localities. The chief sources are the Cornish mines, in which it occurs as tin-stone or tin dioxide; but it is also found in Malacca, Mexico, and Borneo. It is common to find traces of copper, arsenic, and other metals in English tin.

Preparation.—The tin ore is crushed and heated with charcoal and lime; the tin then fuses out.

TIN WITH OXYGEN forms two oxides—

(1) Stannous oxide, SnO.
(2) Stannic oxide, SnO_2.

Stannous oxide (SnO) is a black powder, and forms with acids the stannous salts, the most important of which is stannous chloride, $SnCl_2$. This is termed "the salts" in commerce, and is used as a "mordant." Stannic oxide (SnO_2) occurs as the native tin-stone, but it can be artificially prepared in two conditions, possessing entirely different properties. If nitric acid be added to tin, a white powder is produced which is insoluble in acids; but if an alkali be added to stannic chloride, a white precipitate of stannic oxide results, and this is easily soluble in acids. The salts formed by the soluble stannic oxide are termed stannates, those produced by the insoluble oxide, meta-stannates. "Tin prepare liquor" is a sodium stannate ($Na_2SnO_3,4H_2O$.)

Stannic oxide forms with acids the stannic salts, the most important of which is the following: Stannic chloride ($SnCl_4$).

Two sulphides of tin also exist:

(1) Stannous sulphide, SnS, a blackish-grey substance, and

(2) Stannic sulphide, SnS_2, a bright yellow crystalline powder called *Mosaic gold.*

Tests for the Tin compounds—

For the *Stannous* salts:

(1) Sulphuretted hydrogen gives a dark brown precipitate.

(2) Gold chloride gives the beautiful "*purple of Cassius.*"

(3) The stannous salts have also the property of reducing other metallic solutions. Thus—

$$HgCl_2 + SnCl_2 = HgCl + SnCl_3 = Hg + SnCl_4.$$

The mercuric chloride ($HgCl_2$) is reduced first to white mercurous chloride (HgCl), and finally to black metallic mercury (Hg), the stannous chloride ($SnCl_2$) acquiring more chlorine, and passing into the stannic chloride ($SnCl_4$).

For the *Stannic* salts:

(1) Sulphuretted hydrogen gives a yellow precipitate.

(2) Gold chloride gives *no* precipitate.

GROUP VII.—THE ANTIMONY GROUP.

ANTIMONY. | BISMUTH.

Arsenic is often included in this class, but it has been deemed advisable to place it among the non-metallic elements.

ANTIMONY—STIBIUM.

Symbol, Sb. Combining weight, 122. Specific gravity, 6·71.

Description.—A blueish white, brittle, crystalline metal, melting at 450°C. It undergoes no change in the air at the ordinary temperature, but when heated strongly, takes fire, burning with a white flame, and giving off dense white fumes of antimonic oxide (Sb_2O_5). It is unattacked by dilute sulphuric or hydrochloric acid, but is converted by nitric acid into white insoluble antimonic acid ($HSbO_3$). Alloys of antimony are used extensively in the arts. The most important alloy is type metal (lead and antimony), which contains 17 to 20 per cent. of antimony.

Antimony with Oxygen forms three oxides—

(1) Antimonious oxide, or trioxide, Sb_2O_3.
(2) Antimonious-antimonic oxide, Sb_2O_4.
(3) Antimonic oxide, or pentoxide, Sb_2O_5.

Antimonious oxide (Sb_2O_3) sometimes called antimonious acid, is a white powder, and gives rise to the salts of antimony used in medicine. It is best prepared by decomposing the antimonious chloride ($SbCl_3$) with carbonate of soda (Na_2CO_3). Thus—

$$2SbCl_3 + 3Na_2CO_3 = 3CO_2 + 6NaCl + Sb_2O_3.$$

Carbonic anhydride, common salt, and antimonious oxide result.

Tartar emetic ($KSbC_4H_4O_7$) is prepared from acid tartrate of potash ($KHC_4H_4O_6$) and antimonious oxide (Sb_2O_3), and may be regarded as acid tartrate of potash, the hydrogen of which is replaced by a radical SbO. Thus—

Acid tartrate of potash $= K\ H\ C_4H_4O_6$.
Tartar emetic $= K(SbO)C_4H_4O_6$.

Sources and Preparation.—Metallic antimony is found native, but the chief ore is the trisulphide. By heating the sulphide with about half its weight of metallic iron, ferrous sulphide and metallic antimony are formed; and the metal may be reduced by heating the ore, mixed with coal, in a reverberatory furnace.

Antimonic oxide (called sometimes antimonic acid), Sb_2O_5, is a light straw-coloured powder, losing oxygen at a red heat, and being converted into an intermediate oxide, Sb_2O_3,Sb_2O_5, or $2Sb_2O_4$. Antimonic oxide may be prepared by the action of nitric acid upon antimony, and yields monobasic salts termed antimoniates. It may also be prepared by decomposing the pentachloride with water, and in this mode forms dibasic salts, to which the name of met-antimoniates is given.

Antimonious-antimonic oxide (Sb_2O_4) is prepared by heating the metal in the air until no further change occurs.

Metallic antimony, in fine division, takes fire spontaneously in chlorine gas.

The chlorides of antimony are two in number:

(1) Antimony trichloride, $SbCl_3$,

A buttery mass, prepared by passing chlorine gas over an excess of metallic antimony, and

(2) Antimony pentachloride, $SbCl_5$,

A strongly fuming, mobile liquid, prepared by pouring excess of chlorine over the trichloride of antimony.

There are two sulphides of antimony:

The trisulphide, SbS_3, and the pentasulphide, SbS_5.

Antimoniuretted hydrogen (SbH_3) is a gas corresponding to arseniuretted hydrogen (AsH_3). It is given off when zinc and a dilute mineral acid are brought into contact with an antimony salt, exactly in the same manner as arseniuretted hydrogen (AsH_3) is prepared.

Tests for the Antimony Compounds—

(1) Sulphuretted hydrogen gives an *orange* precipitate, soluble in sulphide of ammonium. (This is the *only* orange sulphide.)

(2) The chloride thrown into water gives a white precipitate.

(3) Zinc and iron reduce the antimonial salts to the metallic state as a black powder.

(4) SbH_3 burns and deposits two rings on a white plate held *in* the flame. These rings are soluble in sulphide of ammonium, but not in a solution of chlorinated lime, thus distinguishing the gas from arseniuretted hydrogen.

(5) Infusion of cinchona, and any solution of tannic acid, produces a copious dirty-brown precipitate with the salts of antimony.

BISMUTH (Wismuth, *German*, a beautiful meadow).

Symbol, Bi. Combining weight, 210. Specific gravity, 9·8.

Description, Sources, and Preparation.—A pinkish white, brittle, crystalline metal. Melts at 264°C, and volatilises at a white heat. When heated strongly it burns with a blue flame, and it takes fire when thrown into chlorine gas. Some of the compounds are used in medicine, and some in the arts as pigments.

Bismuth occurs native in small quantities, but its chief ore is the sulphide.

The metal may be procured by the simple exposure of its ore to heat. It forms bivalent, trivalent, and quinquivalent salts.

BISMUTH WITH OXYGEN forms two oxides—

(1) Bismuthous oxide, Bi_2O_3.
(2) Bismuthic oxide, Bi_2O_5.

Bi_2O_3 is a pale yellow powder, formed by roasting the metal in the air. Bi_2O_5 is a reddish-brown powder, prepared by dissolving Bi_2O_3 in potash and precipitating the bismuthic oxide by heat and nitric acid.

Sulphide of bismuth, Bi_2S_3, is an insoluble black substance. The trichloride, $BiCl_3$, is formed by heating the metal in chlorine. The salts used in medicine are the subnitrate, $BiNO_4,H_2O$, a soluble salt, the carbonate, $2(Bi_2CO_5)H_2O$, and the oxide, Bi_2O_3.

Tests for the Bismuth Compounds—

(1) Sulphuretted hydrogen gives a black precipitate.

(2) Solutions of these salts become *milky* upon the addition of water, insoluble basic compounds being formed.

(3) Metallic bismuth is easily reduced from its compounds before the blow-pipe as a brittle bead.

General Characteristics of the Antimony Group.

These metals are triads; they form a junction line between the metallic and the non-metallic substances, and are closely allied to phosphorus in their properties.

GROUP VIII.—THE LEAD GROUP.

LEAD—PLUMBUM (means something heavy).

Symbol, Pb. Combining weight, 207. Density, 11·3.

Description.—A blueish white metal, so soft that it can be scratched with the nail, may be drawn out into coarse wire, or hammered into plate, but has little elasticity or tenacity. Lead melts at 334° C. It is a dyad metal. In dry air, the surface of the metal remains bright, but in moist air it soon tarnishes from oxidation, and the oxidising process proceeds rapidly if a small quantity of weak acid, such as carbonic or acetic acid, be present. Lead preserves its lustre in pure water freed from air; but should air be present, then oxide of lead is formed, and by the solution of this in water successive portions of the metal are exposed for oxidation. Waters containing *nitrates* and *chlorides*, or much *free carbonic acid*, are *prone to impregnation* with lead, but the hard waters in which are *sulphates* and *carbonates* may safely be brought in contact with the metal, since a thin deposit of carbonate or sulphate of lead is formed, which prevents further action.

Sources.—Not found native; chiefly obtained from the sulphide of lead or galena, PbS.

Preparation.—By roasting galena in a reverberatory furnace with a small amount of lime to form a fusible slag with any silicious mineral matter present. A portion of the sulphide of lead is oxidised to sulphate ($PbSO_4$), another portion of sulphur comes off as sulphur dioxide (SO_2), and oxide of lead (PbO) is left. The lead sulphate and lead oxide both decompose the remaining sulphide, and sulphur dioxide and metallic lead remain. Thus—

$$(1)\ PbSO_4 + PbS = 2Pb + 2SO_2.$$
$$(2)\ 2PbO + PbS = 3Pb + SO_2.$$

LEAD WITH OXYGEN forms three compounds :

(1) PbO, lead monoxide, litharge, a straw-coloured powder.
(2) PbO_2, lead dioxide, the puce-coloured oxide.
(3) Pb_3O_4 ($2PbO + PbO_2$), red lead.

PbO, litharge, or massicot, is prepared in scaly crystals (1) by heating the carbonate of lead to dull redness. Thus—

$$PbCO_3 + \text{heat} = CO_2 + PbO.$$

Or (2) by heating lead in a current of air.

This oxide is soluble in caustic potash (KHO), and forms with acids the important series of lead salts, most of which are white, and the soluble ones are poisons. With silica, PbO forms an easily fusible silicate or glass.

PbO_2, the puce-coloured oxide, is prepared by (1) passing chlorine through the hydrated monoxide (PbH_2O_2). Thus—

$$PbH_2O_2 + 2Cl = 2HCl + PbO_2.$$

Or by (2) digesting red lead (Pb_3O_4) with nitric acid (HNO_3). Thus :

$$Pb_3O_4 + 4HNO_3 = 2H_2O + 2Pb2NO_3 + PbO_2.$$

Water, lead nitrate, and the puce-oxide are formed. PbO_2 forms no salts with acids.

Pb_3O_4 is prepared by heating the monoxide for a long time, and thus acquiring more oxygen. Thus—

$$3PbO + O = Pb_3O_4.$$

Lead nitrate, $Pb2NO_3$, is the most important of the *soluble* lead salts. It is prepared by dissolving the oxide, the carbonate, or metallic Pb, in warm HNO_3. It crystallises in octahedra, dissolves in eight parts of cold water, and when strongly heated yields N_2O_4.

Lead acetate, $Pb(C_2H_3O_2)_2$, or sugar of lead, is also a soluble salt.

Lead carbonate, $PbCO_3$, occurs native as cerusite, and is insoluble.

White Lead is a compound of lead carbonate and lead hydroxide, and it may be represented by the formula $2PbCO_3 + PbH_2O_2$.

Galena, or lead sulphide (PbS), is the chief ore of the metal, and is found native. It may be prepared as a black precipitate by passing H_2S through a solution of a lead salt. Galena has a bright blueish-white metallic lustre, and crystallises in cubes and octahedra.

Lead sulphate ($PbSO_4$) is a white insoluble salt, found native, but prepared artificially by adding H_2SO_4 to a soluble lead salt.

Lead chloride, $PbCl_2$, is prepared by the addition of hydrohloric acid to a solution of nitrate of lead. It dissolves in thirty parts of boiling water, and appears as shining needles on cooling.

Lead iodide, PbI_3, is precipitated as beautiful yellow spangles by mixing together hot solutions of iodide of potassium and nitrate of lead, and allowing the mixture to cool.

Lead chromate, $PbCrO_4$, is a yellow insoluble salt called chrome yellow.

Tests for the Lead Compounds—

(1) Sulphuretted hydrogen gives a black precipitate.
(2) Alkalies give white precipitates.
(3) Sulphuric acid gives an insoluble white precipitate.
(4) Iodide of potassium gives a yellow precipitate.
(5) Bichromate of potash gives a yellow precipitate.
(6) Charcoal, sodium carbonate, and the blow-pipe yield the metal which is malleable.

GROUP IX.—THE SILVER GROUP.

Copper. | Mercury. | Silver.

COPPER—Cuprum (from Cyprus).

Symbol, Cu. Combining weight, 63·5. Specific gravity, 8·93.

Description.—A deep-red-coloured metal, very ductile and malleable, and possessed of much tenacity. Melts at a red heat, and slightly volatilises at a white heat, giving a green tint to the hydrogen flame when that gas is passed over it; one of the best conductors of electricity and heat. This metal does not oxidise in pure dry or moist air at ordinary temperatures, but when heated to redness, it readily oxidises to scales of copper oxide.

Brass is an alloy containing about $\frac{2}{3}$ of copper and $\frac{1}{3}$ of zinc. The yellow or muntz-metal contains 60 per cent. of copper, and is used for sheathing ships. Bronze, gun-metal, bell-metal, and speculum-metal are alloys of tin and copper in varying proportions. These alloys all possess the remarkable property of being hard and brittle when slowly cooled, but of becoming malleable and soft when suddenly cooled by being dipped when red-hot into cold water.

Sources.—Copper occurs native in North America, and in a few other localities, but it is chiefly obtained from the following ores:

(1) Copper pyrites ... ... $Cu_2S + Fe_2S_3$.
(2) Cuprous sulphide ... ... Cu_2S.
(3) Malachite or the carbonate ... $CuCO_3,CuH_2O_2$.
(4) Cuprous oxide or the red oxide ... Cu_2O.

The Cornish mines yield considerable quantities of copper, and Chili and South Australia are rich in copper ores.

Preparation.—(1) By reducing the oxide in a current of hydrogen.

(2) By the electrolytic decomposition of a salt of copper.

Metallic copper is easily prepared on a large scale from the carbonate or oxide, but when the copper pyrites ($Cu_2S + Fe_2S_3$) is employed, the process is more difficult. The ore is then roasted continually, to convert the cuprous sulphide into the oxide, and then sand or silicious slag is added to the ore, which is then roasted in a reverbatory furnace; the cuprous oxide becomes converted into the cuprous sulphide, and the iron oxidising and uniting with the silica forms a light fusible slag. The impure cuprous sulphide fuses and sinks to the bottom of the furnace, and in this manner a coarse metal or "mat" is formed. By a repetition of the process, pure cuprous sulphide or "fine metal" is produced. In order to free the metallic copper from sulphur, the fine metal is roasted and subsequently fused in the air. In the earlier part of the process, part of the sulphur is burnt off with the formation of cupric oxide (CuO), and at a later period the remainder of the sulphide is acted upon by the oxide forming sulphur dioxide (SO_2), and metallic copper (Cu). Thus—

$$Cu_2S + 2CuO = SO_2 + 4Cu.$$

The last traces of oxide are got rid of by "poling," *i.e.*, stirring up the molten copper with a piece of green wood.

COPPER WITH OXYGEN forms two oxides—

(1) The cuprous oxide or red suboxide, Cu_2O.
(2) The cupric oxide or black peroxide, CuO.

CUPROUS OXIDE, Cu_2O,

Is found native in ruby-red octahedra, but it may be prepared artificially by (1) heating together equal quantities of the black oxide (CuO) and copper filings; or (2) by boiling a solution of sulphate of copper ($CuSO_4$) and caustic potash (KHO) with glucose, or grape sugar. The black oxide is first precipitated by the caustic potash, and subsequently reduced by the glucose, to a bright red powder. A beautiful ruby-red colour is communicated to glass by cuprous oxide.

All the cuprous compounds rapidly absorb oxygen from the air, and pass into the corresponding cupric salts. Of the cuprous salts the most important is the

CUPROUS CHLORIDE, $CuCl$.

This is a white solid, and is remarkable for absorbing carbonic oxide gas.

CUPRIC OXIDE, CuO,

May be obtained (1) by heating copper in the air, or (2) by heating cupric nitrate ($Cu2NO_3$) to redness. This oxide yields the green and blue cupric salts.

The hydrated cupric oxide, CuH_2O_2 is thrown down as a light blue precipitate when liquor potassæ (KHO) is added to a cupric salt, as for instance, to the sulphate of copper ($CuSO_4$). Thus—

$$CuSO_4 + 2KHO = K_2SO_4 + CuH_2O_2.$$

Sulphate of potash and hydrated cupric oxide are formed.

By boiling the hydrate, the water, H_2O is given off, and the black oxide, CuO, is thrown down.

The most important soluble cupric compounds are the following:

CUPRIC SULPHATE, $CuSO_4$, $5H_2O$.

This is known as "blue vitriol," and is obtained in large blue crystals by the action of heat, sulphuric acid, and water upon metallic copper; when heated to redness, $CuSO_4$, $5H_2O$, loses its water of crystallisation and falls to a white powder.

CUPRIC NITRATE, $Cu2NO_3$, $6H_2O$,

Is obtained in large blue prisms by dissolving copper in nitric acid.

CUPRIC CHLORIDE, $CuCl_2$, $2H_2O$,

Is formed when finely divided metallic copper is placed in chlorine gas, or when CuO is acted upon by hydrochloric acid. It occurs in green needle-shaped crystals, an alcoholic solution of which burns with a peculiar green flame.

Amongst the insoluble cupric salts, are the

CUPRIC SULPHIDE, CuS.

A black precipitate formed by the addition of sulphuretted hydrogen to an acid solution of a copper salt.

CUPRIC CARBONATE, $CuCO_3$, CuH_2O_2.

A green precipitate, not known pure, but always containing the hydrated oxide, and obtained by adding any alkaline carbonate to a copper salt.

CUPRIC ARSENITE, SCHEELE'S GREEN, $CuHAsO_3$.

A bright green powder, obtained by mixing an alkaline arsenite with cupric sulphate.

Tests for the Copper Compounds—

(1) Liquor potassæ gives a pale blue precipitate, turning black on boiling.

(2) Liquor ammoniæ (a few drops of) gives a pale blue precipitate, which is dissolved by excess of ammonia, forming a beautiful *sapphire-blue* solution; a remarkable compound is here formed, the composition of which is $CuSO_4 + 2NH_3$, and this is capable of crystallisation. It may be regarded as ammonium sulphate $[(NH_4)_2SO_4]$, in which an atom of dyad copper has replaced two atoms of monad hydrogen. Thus—

$$\left.\begin{matrix}NH_4\\NH_4\end{matrix}\right\}SO_4 \quad \ldots \quad \ldots \quad \ldots \quad \left.\begin{matrix}NH_4\\NH_2Cu\end{matrix}\right\}SO_4.$$

(3) Ferrocyanide of potassium gives a *chocolate* precipitate of ferrocyanide of copper.

(4) Sulphuretted hydrogen gives a black precipitate.

(5) A polished steel needle or knife dipped in a solution of copper receives a red coating of metallic copper.

MERCURY—HYDRARGYRUM (Hudor, water, arguros, silver).

Symbol, Hg. Combining weight, 200. Specific gravity, at 0°C., 13·596. Density, 100.

Description.—The only metal liquid at the ordinary temperature. White and volatile. Freezes at 39·4°C., and boils at 350°C.; when pure, mercury does not tarnish in dry or moist air, but above 300°C. it absorbs oxygen and passes into the red oxide. It is a dyad metal, and is largely employed in the processes for extracting silver and gold from their ores. Both the metal and its salts are of great medicinal value.

Sources and Preparation.—Found native, and as the sulphide (cinnabar) in Spain, California, Japan, and China. The cinnabar is roasted; the sulphur is evolved as sulphur dioxide (SO_2), the metal volatilises, and the vapour is condensed in earthen pipes.

MERCURY WITH OXYGEN forms two oxides, viz.—

(1) Mercurous oxide or black suboxide, Hg_2O.
(2) Mercuric oxide or red peroxide, HgO.

MERCUROUS OXIDE (Hg_2O),

Is a dark grey powder, seen also in *black wash*, and is propared by precipitating the mercurous chloride (HgCl) by means of liquor potassæ (KHO). Thus—

$$2HgCl + 2KHO = 2KCl + H_2O + Hg_2O.$$

Chloride of potassium, water, and mercurous oxide are formed.

MERCURIC OXIDE, HgO,

Occurs in red crystals, which appear yellow when finely powdered, and may be prepared by (1) heating the mercuric nitrate, or (2) by the addition of liquor potassæ (KHO) to the mercuric nitrate ($Hg2NO_3$). Thus—

$$Hg2NO_3 + 2KHO = 2KNO_3 + H_2O + HgO.$$

Nitrate of potash, water, and mercuric oxide result.

MERCUROUS SULPHIDE, Hg_2S,

Is a black substance, obtained by the addition of sulphuretted hydrogen to a mercurous salt.

MERCURIC SULPHIDE, Vermilion, or Cinnabar, HgS,

Is a red substance, and occurs native, but it may be artificially prepared by heating sulphur and mercury together, or by the addition of an excess of sulphuretted hydrogen to a mercuric salt. In this last method the sulphide is black, but when sublimed it becomes red.

MERCURY WITH CHLORINE forms two chlorides, viz.—

(1) Mercurous chloride, or calomel, HgCl.
(2) Mercuric chloride, or corrosive sublimate, $HgCl_2$.

MERCUROUS CHLORIDE, SUBCHLORIDE OF MERCURY, CALOMEL, HgCl,

Is a white, insoluble powder, and is prepared—

(1) By heating metallic mercury (Hg) with corrosive sublimate ($HgCl_2$). Thus—

$$Hg + HgCl_2 = 2HgCl.$$

Or (2) (*a*) By adding metallic Hg to the mercuric sulphate ($HgSO_4$). Thus—

$$Hg + HgSO_4 = Hg_2SO_4 \text{ (the mercurous sulphate).}$$

(*b*) Chloride of sodium (NaCl) is added to the mercurous sulphate (Hg_2SO_4). Thus—

$$Hg_2SO_4 + 2NaCl = Na_2SO_4 + 2HgCl.$$

Sulphate of sodium and calomel are formed.

The calomel sublimes, and forms a solid cake, which is well washed to get rid of any mercuric chloride that may be formed in the preparation.

MERCURIC CHLORIDE, PERCHLORIDE OF MERCURY, CORROSIVE SUBLIMATE, $HgCl_2$,

Occurs in semi-transparent masses or prisms, which are insoluble in water, and very poisonous.

It is prepared by the addition of chloride of sodium ($NaCl$) to the mercuric sulphate ($HgSO_4$). Thus—

$$HgSO_4 + 2NaCl = Na_2SO_4 + HgCl_2.$$

Sulphate of sodium and mercuric chloride are formed.

When liquor ammoniæ (NH_4HO) is added to $HgCl_2$, "white precipitate," or HYDRARGYRUM AMMONIATUM, NH_2HgCl, is formed. Thus—

$$HgCl_2 + NH_4HO = H_2O + HCl + NH_2HgCl.$$

Water, hydrocloric acid, and "white precipitate" result.

MERCUROUS NITRATE, $HgNO_3$,

Is obtained by the action of dilute nitric acid upon an excess of metallic mercury.

MERCURIC NITRATE, $Hg2NO_3$,

Is obtained by the action of excess of nitric acid upon metallic mercury, or the mercuric oxide.

Tests for the Mercury Compounds—

(1) All the mercurial salts sublime, and can be decomposed by heat.

(2) By charcoal and sodium carbonate, metallic mercury is obtained. (The reduction test.)

(3) Bright copper strips when placed in an acidulated solution become coated with metallic mercury.

(4) Stannous chloride ($SnCl_2$) in excess precipitates the metal (black).

(5) Bright gold or copper moistened with a solution of mercury, and touched with a pointed steel, becomes coated with a white silvery stain.

Tests for the Mercurous Salts—

(1) Liquor calcis (CaH_2O_2), and all the alkalies, throw down a *black* precipitate ("black wash").

(2) Iodide of potassium (KI) gives an *olive green* precipitate.

(3) Chromate of potash (K_2CrO_4) gives a *bright red* precipitate.

(4) Sulphuretted hydrogen gives a *black* precipitate.

Tests for the Mercuric Salts—

(1) Liquor calcis and all the alkalies, except ammonia, give a *yellow* precipitate ("yellow wash").

(2) Liquor ammoniæ gives a *white* precipitate.

(3) Iodide of potassium gives the *scarlet* iodide of mercury soluble in excess of either re-agent.

(4) Sulphuretted hydrogen in excess gives a *black* precipitate, becoming *red* when sublimed.

SILVER—ARGENTUM (Arguros, silver, from argos, white).

Symbol, Ag. Combining weight, 108. Specific gravity, 10·5.

Description.—A brilliant white metal, a great conductor of electricity and heat, and very ductile. Silver is a monad metal, and is easily dissolved by nitric acid, with the evolution of nitric oxide gas; the metal readily unites with sulphur, forming the black sulphide.

Sources.—Found native, but more generally combined with antimony, sulphur, chlorine, and bromine. Galena, or lead sulphide, also contains small quantities of silver.

Preparation.—The silver ore is roasted in a furnace with common salt, by which means the silver chloride is formed. Iron scraps (Fe) are then added. Thus—

$$6AgCl + 2Fe = Fe_2Cl_6 + 6Ag.$$

Perchloride of iron and metallic silver are formed.

Metallic mercury is then added, and thus a liquid amalgam of silver and mercury is formed. By distilling off the mercury, the silver remains. When silver is melted in the air, it absorbs twenty-two times its bulk of oxygen, the gas being again evolved upon the solidification of the metal. This process is known as "spitting." Silver is usually alloyed with small quantities of copper for preparing articles of plate and coinage. English silver money contains 7·5 per cent. of copper.

SILVER WITH OXYGEN forms three oxides, viz.—

(1) Silver suboxide, Ag_4O, a black powder.

(2) Silver monoxide, Ag_2O, a brown substance obtained by the addition of liquor potassæ to a solution of nitrate of silver.

(3) Silver dioxide, Ag_2O_2, a black powder, prepared when ozone acts upon metallic silver.

SILVER NITRATE, $AgNO_3$,

Is the most important of the *soluble* salts of silver. It is prepared by the action of nitric acid upon metallic silver and evaporating the solution. It then appears as large translucent tabular crystals. Upon heating, nitrate of silver fuses easily, and when cast into sticks it is known by the name of "lunar caustic." It blackens the skin.

Silver Chloride, AgCl,

Is the most important *insoluble* salt of silver. It occurs native as "horn silver," and may be obtained as a white curdy precipitate when a silver salt and a soluble chloride are brought into contact. By exposure to light, this salt becomes of a purple tint, increasing in shade according to the length of time of its exposure.

Chloride of silver is readily soluble in hyposulphite of sodium.

Silver Bromide, AgBr,

Is a white substance, obtained by adding an alkaline bromide to silver nitrate.

Silver Iodide, AgI,

Is a yellow powder.

Silver Sulphide, Ag_2S,

Occurs native as "silver-glance," and may be obtained as a black precipitate by passing sulphuretted hydrogen gas through a solution of a salt of silver.

Tests for the Silver Compounds—

(1) Hydrochloric acid gives a *white* precipitate (AgCl), *soluble* in liquor ammoniæ.

(2) Alkalies (KHO, &c.), give a *brown* precipitate of Ag_2O, soluble in excess of liquor ammoniæ.

(3) Sulphuretted hydrogen gives a black precipitate (Ag_2S), insoluble in sulphide of ammonium.

(4) Iron, copper, and mercury give a white precipitate (Ag).

(5) Chromate or bichromate of potash gives a *brown* precipitate.

(6) Tribasic phosphate of sodium gives a *yellow* precipitate.

General Characteristics of the Silver Group.

Under no circumstances is water decomposed by these metals. They are all oxidised by strong sulphuric and nitric acids. Silver is a monad; but mercury and copper are dyads.

GROUP X.—THE GOLD GROUP.

Gold. | Platinum.

GOLD—Aurum.

Symbol, Au. Combining weight, 197. Specific gravity, 19·3.

Description.—A soft, yellow metal, soluble in nitro-hydrochloric acid, and in selenic acid. A triad metal, and the most malleable of all the metals, since it can be beaten into leaves

$\frac{1}{100,000}$ of an inch in thickness. It remains untarnished in dry or moist air at any temperature, and is unaffected by sulphur.

The *Standard Gold* of England is an alloy of copper and gold, and contains 8·33 per cent. of the former. This alloy is less ductile than the pure metal, but possesses greater fusibility and hardness.

Sources.—Always found in the metallic state. It occurs in the plutonic rocks, but is also found in the sand of most rivers. It is a widely diffused metal, although occurring only in small quantities.

Preparation.—The sand, or "detritus" in which the metal is contained, is washed in a "cradle," and thus the lighter mud is washed away, whilst the heavier gold grains sink to the bottom.

To obtain pure gold, the ordinary metal is dissolved in aqua regia, and thus terchloride of gold is formed ($AuCl_3$), then ferrous sulphate ($FeSO_4$) is added. Thus—

$$2AuCl_3 + 6FeSO_4 = 2Fe_2(SO_4)_3 + Fe_2Cl_6 + 2Au.$$

Ferric sulphate and ferric chloride are formed, and metallic gold is precipitated as a brown powder.

GOLD WITH OXYGEN forms two oxides, viz.—

(1) Aurous suboxide, Au_2O.
(2) Auric trioxide, Au_2O_3.

Neither of these substances forms any salts with acids, but Au_2O_3 unites with bases to form *aurates.* Thus aurate of sodium is $NaAuO_2$.

"*Fulminating Gold*" is prepared by the action of excess of liquor ammoniæ upon a solution of gold. In this process a brownish-yellow powder is thrown down, which when dry and heated to 100°C. explodes very readily when struck by a hammer, or even spontaneously.

AUROUS CHLORIDE, $AuCl$.

Is a white insoluble mass, obtained by heating auric chloride to 235°C.

AURIC CHLORIDE, $AuCl_3$,

Is obtained by dissolving metallic gold in aqua regia.

Tests for the Gold Compounds—

(1) Ferrous sulphate gives a *brown* precipitate of metallic gold.

(2) The blow-pipe gives a metallic bead of gold.

(3) Stannous chloride gives the "*purple of Cassius.*"

PLATINUM (Platina, silver).

Symbol, Pt. Combining weight, 197·4. Specific gravity, 21·5.

Description.—A bright white metal, never tarnishing, very infusible, and only to be melted in the oxy-hydrogen blowpipe flame. A tetrad metal. Is only dissolved by aqua regia. Finely divided metallic platinum is remarkable for its power of condensing gases on its surface.

Sources.—A comparatively rare metal, always occurring native, and generally alloyed with the metals palladium, rhodium, iridium, osmium, and ruthenium.

Preparation.—Platinum was originally prepared by dissolving its ore in aqua regia, and precipitating the metal with chloride of ammonium as ammonio-platino-chloride. When this precipitate is heated, "*spongy*" or finely-divided platinum is formed. If this sponge, when hot, be hammered and forcibly pressed, it gradually assumes a coherent mass by the "*welding*" of the platinum particles.

A method lately adopted has been to melt the ore with the oxyhydrogen blow-pipe in a very powerful furnace. By this means a pure alloy of platinum, rhodium, and iridium is formed, whilst the impurities are volatilised by the intense heat. This pure alloy is harder, and not so easily attacked by acids as the pure platinum.

PLATINUM WITH OXYGEN forms two oxides, viz.—

(1) Platinum monoxide or platinous oxide, PtO.
(2) Platinum dioxide or platinic oxide, PtO_2.

PLATINUM MONOXIDE is a black powder.

PLATINUM DIOXIDE can be prepared as a brown hydrate by the addition of liquor potassæ to a solution of platinum nitrate. Upon heating the hydrate, the anhydrous oxide is first formed, and subsequently the metal is precipitated.

PLATINUM DICHLORIDE, OR PLATINOUS CHLORIDE, $PtCl_2$

Is an insoluble greenish-grey powder, prepared by heating the following chloride to 200°C.

PLATINUM TETRACHLORIDE, OR PLATINIC CHLORIDE, $PtCl_4$

Is a red or brown deliquescent mass, obtained by dissolving the metal in aqua regia, and evaporating the solution to dryness.

Tests for the Platinum Compounds—

(1) Sulphuretted hydrogen gives a brown precipitate soluble in excess of sulphide of ammonium.

(2) Metallic zinc throws down metallic platinum.

(3) The platinic chloride ($PtCl_4$) gives a *yellow* granular precipitate (falling slowly) with potash and ammonia, but not with soda, and is of great use in analysis for the separation of potash and soda.

General Characteristics of the Gold Group.

These metals, with silver and mercury, constitute the noble metals. Gold and platinum are not acted upon by nitric acid, but only by chlorine or aqua regia.

Gold is a triad, and platinum a tetrad metal.

APPENDIX.

An *Atom* is the smallest quantity to which an elementary substance can be reduced. It is to be regarded as a definite quantity, and although the atoms of all bodies are assumed to be of the same size, yet they vary greatly in weight. If the atom of hydrogen be taken as the standard of comparison, and counted to weigh 1, then the atom of oxygen will be found to weigh 16; that of nitrogen 14; and that of sulphur 32. These numbers are therefore termed the *atomic weights*. An atom is the smallest quantity that can enter into combination with another element.

An atom *must be united to another atom,* it cannot exist alone as such, and the two (or more as frequently happens) constitute a molecule. Thus H, O, and N are atoms, and can combine with other bodies, but, when free, they combine with one of their own atoms, and actually exist as H_2, O_2, N_2, *i.e.*, as molecules. One atom in union with another forms a molecule, whether the element be the same or not; thus H and H form a molecule of hydrogen; H and Cl = a molecule of HCl, hydrochloric acid; H, C, and N = a molecule of HCN, hydrocyanic acid. A molecule may, however, consist of 2, 3, 4, or even more atoms, as observed in a molecule of water, H_2O (3 atoms), or of ammonia, NH_3 (4 atoms), &c.

Now although atoms combine in certain definite proportions, their power of replacing one another in compound bodies greatly varies; 1 atom of oxygen may replace 2 atoms of hydrogen in any compound; 1 atom of nitrogen will replace 3 of hydrogen: and 1 atom of carbon will take the place of 4 atoms of hydrogen or 2 atoms of oxygen.

This has led to an arrangement into groups showing the power in atoms of replacing each other in chemical compounds, and this is called their *quantivalence.*

The elementary atoms are divided into monads or univalents, dyads or divalents, triads or trivalents, tetrads or tetravalents, pentads or pentavalents, hexads or hexavalents; the elements themselves being termed monatomic, diatomic, triatomic, tetratomic, &c., in accordance with the number of hydrogen atoms which one atom of each can replace, since the atom H is taken as the standard for comparison, and is the typical monad.

The elements of *even* quantivalence, viz.: the dyads, tetrads, and hexads, are called *Artiads*, and those of *uneven* quantivalence, viz.: monads, triads, and pentads, are known as *Perissads*.

Not only can the elements be considered to possess varying atomicity, but so can the groups of elementary substances, acting collectively as elements, and which are termed "*compound radicals*," viz.: NO_2, SO_2, PO, as will immediately be seen. Nitric acid (HNO_3) may be considered as water (H_2O), in which one atom of H is replaced by a *monad radical*, NO_2. Thus—

$\left.\begin{matrix}H\\H\end{matrix}\right\}O$ water ... ... $\left.\begin{matrix}H\\NO_2\end{matrix}\right\}O$ nitric acid.

Sulphuric acid (H_2SO_4) may be regarded as 2 molecules of water, in which two atoms of H are replaced by the *dyad radical* SO_2. Thus—

$\left.\begin{matrix}H_2\\H_2\end{matrix}\right\}O_2$ water ... ... $\left.\begin{matrix}H_2\\SO_2\end{matrix}\right\}O_2$ sulphuric acid.

Tribasic phosphoric acid (H_3PO_4) may be looked upon as 3 molecules of water, in which 3 atoms of H are replaced by the *triad* radical PO. Thus—

$\left.\begin{matrix}H_3\\H_3\end{matrix}\right\}O_3$ water ... ... $\left.\begin{matrix}PO\\H_3\end{matrix}\right\}O_3$ phosphoric acid.

But although the non-metallic and metallic radicals are classified into univalent and multivalent groups, it must be stated that with the exception of hydrogen, which is always univalent, all the other radicals may exhibit different degrees of quantivalence. Observe the oxides of nitrogen, N_2O, N_2O_2, N_2O_3, N_2O_4, N_2O_5. Here, from the formulæ, nitrogen may range from a monad to a pentad inclusive. Carbon is *tetrad* in marsh gas, CH_4, and in carbonic anhydride, CO_2, but only *dyad* in carbonic oxide, CO. Sulphur is *hexad* in sulphuric anhydride, SO_3, and *dyad* in sulphuretted hydrogen, H_2S. Iron may be *dyad* at one time, as in ferrous chloride, $FeCl_2$, and *triad* at another, as in ferric chloride, Fe_2Cl_6.

LAWS REGULATING CHEMICAL COMBINATIONS

Are as follows :—

1*st.* The law of *Constant proportion.*—The same substance always contains the same elements united in the same proportions.

2nd. The law of *Multiple proportion*.—When one body combines with another in several proportions, the higher proportions are always multiples of the first or lowest.

3rd. The law of *Reciprocal proportion*.—If two bodies unite with a third, the proportions in which they combine with that third body are measures or multiples of the proportion in which they combine with each other.

The combining quantity of a compound body is the sum of the combining proportions of its constituents. Thus water, H_2O – 2 for H, and 16 for O = 18, and this is the combining quantity of that fluid; and H_2SO_4, sulphuric acid, would be 2 for H, 32 for S, and 4 times 16 for O, *i.e.*, 64, proving 98 altogether to be its combining proportion, which is the case.

When one atom of an element unites with an atom of another, in several proportions, distinctive names are applied; thus, a metal might unite with oxygen as follows: M_2O, MO, M_2O_3, MO_2, MO_3, MO_4, and to these the terms *suboxide, monoxide, sesquioxide, dioxide, trioxide,* and *tetroxide* would be respectively applied. The resulting compound is always termed an *ide*. If any non-metallic elements were substituted for the oxygen, such as sulphur, iodine, or chlorine, we should have sub-, mono-, sesqui-, di-, tri-, or tetra-, sulphides—iodides, or chlorides, according to the number of atoms of each united with one of the metal.

If an element form two acids, the name of the lower terminates in *ous*, and the higher in *ic*, as nitrous, nitric, sulphurous, sulphuric.

For instance, we have ferrous and ferric salts, mercurous and mercuric, cuprous and cupric, &c. The termination *ous* is synonymous with a proto or sub-salt, and the termination *ic* with a per-salt. Thus the ferr*ous* sulphate ($FeSO_4$) may be called the *proto*sulphate or *sub*sulphate, and the ferr*ic* sulphate ($Fe_2(SO_4)_3$) is termed the *per*sulphate.

It may here be stated that the termination *ic* always implies the presence of more oxygen or of the radical than that contained in *ous*, but that the termination *ide* (unless ox-ide) denotes the absence of oxygen, viz.:

H_2SO_4 (sulphur*ic* acid), H_2SO_3 (sulphur*ous* acid).
H_2S (sulph*ide* of hydrogen, or sulphuretted hydrogen).

In the case of chlorides, bromides, iodides, fluorides, and sulphides, viz.: mercurous and mercuric chlorides, &c., oxygen clearly takes no part at all, and here the *ic* implies a larger amount of the radical than that contained in *ous*.

The composition of any substance may be determined by two methods, viz.: (1) By synthesis, and—

(2) By analysis. The latter may be of two kinds.

(*a*) Qualitative, merely discovering the ingredients.

(*b*) Quantitative, determining the amount of each ingredient.

A *chemical formula* represents a molecule of an element, or of a compound, and serves the following purposes:

(1) It indicates the elements entering into the formation of the molecule.

(2) It shows the number of atoms in the molecule.

(3) It represents a constant weight of the compound, the molecular weight, *i.e.*, the sum of the weights of the atoms in the molecule.

(4) In bodies capable of volatilising, it indicates two volumes of the substance in a state of gas or vapour.

By *a volume* is meant a measure.

The combining volumes of all elementary gases and vapours are equal, except in the case of arsenic and phosphorus, which are only half those of the other elements in the gaseous condition, and those of cadmium and mercury, which are double those of the other elements.

A *chemical equation* consists of a collection of symbols and formulæ, illustrating the condition of substances before and after the assault of the molecules one upon another, and showing the new substances formed.

A solid is a substance, the integrant molecules of which, though probably not in absolute contact, are more or less immobile.

A liquid is that in which the molecules freely move around each other; it therefore readily assumes the form of any vessel in which it may be placed, and retains that form.

A gas is that in which the molecules are so separated that they seem to have lost all attraction to one another, and to have acquired such a property of repulsion that the only obstacle to their still further separation is the pressure of the surrounding matter.

An *amalgam* implies the combination of two or more metals, one of which must be mercury.

An *alloy* implies a combination of metals in which mercury takes no part.

THE ATOMIC THEORY.

John Dalton was the first to enunciate the law of multiple proportion. He asked himself, "Why do the elements combine only in multiples of their several combining proportions?" and upon this question he theorised as follows:

All matter is composed of minute indivisible particles, and these are called *atoms*. Although these atoms do not all possess the same weight, still their relative weights are represented by the combining weights of the elements; the oxygen atom is considered to be 16 times as heavy as the hydrogen atom, and the weights of the oxygen and nitrogen atoms are as 16 to 14.

He also assumed that chemical combination consisted in the individual atoms approximating one to another, and was thus enabled to explain why compounds must contain their constituents in the combining proportions, or in multiples of their proportions, and in no intermediate proportion.

Take, for instance, the compounds of nitrogen with oxygen. The lowest oxide contains one atom of O combined with 2 atoms of N, thus (N) (N) (O); it is therefore termed nitrogen monoxide, N_2O. The next oxide possible of formation must have an additional atom of oxygen. Thus (N) (N) (O) (O), and this is called nitrogen dioxide, N_2O_2. The next compound possible is (N) (N) (O) (O) (O), or nitrogen trioxide, N_2O_3. The next is (N) (N) (O) (O) (O) (O), or nitrogen tetroxide, N_2O_4; and the next (N) (N) (O) (O) (O) (O) (O), or nitrogen pentoxide, N_2O_5.

An atom being indivisible, no intermediate product can be obtained.

Gravity simply denotes weight. Specific gravity means relative weight, or weight compared to a standard.

Density implies the comparative mass, and is frequently employed synonymously with specific gravity, since the two bear so close a relationship, the weight depending upon the amount of the mass.

SPECIFIC WEIGHT OR GRAVITY.

Specific gravity may be defined as *the relative weight of equal volumes of different substances.* Water is taken as the standard of comparison of liquids and solids, and air for gases and vapours. We have to determine the specific gravity of matter in three states, as gas, liquid, and solid.

For Gases.

A glass globe, furnished with a stop-cock, is weighed first full of dry air, then perfectly exhausted by an air pump, and again weighed. The difference gives the weight of the volume of air which the globe contains. We now fill the globe with the gas of which the density is required, and weigh it again, taking care that the changes in pressure and temperature are known. The weight of the empty globe, subtracted from the weight of the globe when filled with gas, gives the weight of gas which the globe contains. Then—

Weight of air : Weight of gas : : 1 : Density of gas.

And thus we obtain the desired density.

For Vapours.

A small globular flask is taken, the neck drawn out to a fine tube, and the whole accurately weighed. The substance of which the vapour density is required, is introduced by warming the flask, and dipping the end of the neck into the fluid. By the cooling and contraction of the air, some of the liquid pressed upon by the external air is forced into the flask, which is now placed in a bath of oil or mercury heated much above the boiling point of the liquid. When the flask is completely filled with the pure vapour of the substance, the neck is sealed by the blow-pipe, and when cool it is again weighed. Thus we know (1) the weight of the flask full of air, and (2) the weight of the flask full of vapour; but we require to know the weight of the empty flask. Now, if we know the capacity of the globe in cubic centimetres, and the weight of 1 c.c. of air, we can obtain this. We break the point of the neck under mercury, which fluid rushes in and fills the flask, excepting the drop of liquid into which the vapour has condensed. Having replaced this by mercury, the latter is measured carefully, and the capacity of the flask is ascertained. Let us suppose this to be 200 c.c. Then the weight of 200 c.c. of air at the temperature of the room, subtracted from the original weight of the flask full of air, gives the weight of the empty flask; this latter weight, subtracted from the weight of the flask filled with vapour, gives the weight of 200 c.c. of the vapour at the temperature at which the flask was sealed. Upon calculating the weight of 200 c.c. of air at the same temperature, we obtain the proportion—

Weight of air : Weight of vapour : : 1 : Density of vapour.

For Liquids.

A vessel of any convenient size is taken, the weight of which is known, and its increase in weight is determined (1) when filled with water, (2) when filled with the given liquid, at the same temperature. We take a flask with a narrow neck, upon which near its middle a mark is made; the weight of this is carefully ascertained. Pure distilled water is now added to the level of the mark, and the flask again weighed. The difference between this and the original weight gives the weight of water taken. After drying, we again fill the flask up to the mark with the liquid the density of which we require, and the weight is again taken. The difference between this and the original weight, is the weight of a volume of the liquid equal to that of the water. Then—

Weight of water : Weight of liquid : : 1 : Density of liquid.

For Solids.

"A solid immersed in a liquid loses a weight equal to the weight of an equal volume of the liquid." We weigh a piece of the solid in air, and then immerse it in water, and again weigh it in that position. By the difference we obtain the weight of an equal volume of water. Then—

$$\left\{\begin{array}{l}\text{Weight of equal}\\ \text{volume of}\\ \text{water}\end{array}\right\} : \left\{\begin{array}{l}\text{Weight of}\\ \text{substance}\\ \text{in air}\end{array}\right\} :: 1 : \text{Density of substance.}$$

Or otherwise, divide weight in air by loss of weight in water, and the quotient will be the density.

If the solid *be lighter than water*, we must first weigh it in air, and then attach to it a solid, heavy enough to sink it, and the weight of which we have determined in air and water. The difference between the loss of weight of the heavy body alone, when immersed in water, and that of the combination when similarly immersed, will give the weight of a volume of water equal to that of the light body, the density of which can be determined by the proportion above.

If the substance *be soluble in water*, it must be weighed in a fluid which does not dissolve it, and the density of which is known. Then we have:

(1) "The relative weights of equal bulks of the substance, and of the liquid in which it was weighed.

(2) The relative weights of equal bulks of the liquid and of water. Hence the weight of a volume of water equal to that of the substance is obtained as follows:

$$\text{Density of liquid} : 1 :: \left\{\begin{array}{l}\text{Weight of liquid}\\ \text{displaced by the}\\ \text{substance}\end{array}\right\} : \left\{\begin{array}{l}\text{Weight of an}\\ \text{equal volume}\\ \text{of water.}\end{array}\right\}$$

Then the density may be obtained in the usual way."

FINIS OF PART II.

TABLE OF QUANTIVALENCE OF THE PRECEDING METALS.

Monads.	*Dyads.*	*Triads.*	*Tetrads.*
POTASSIUM	CALCIUM	ALUMINIUM	FERRUM
SODIUM	STRONTIUM	STIBIUM*	STANNUM
LITHIUM	BARIUM	BISMUTHUM*	PLATINUM
AMMONIUM	MAGNESIUM	AURUM	
CÆSIUM	ZINCUM		
RUBIDIUM	CADMIUM		
ARGENTUM	MANGANESIUM*		
	COBALTIUM*		
	NICKEL*		
	CHROMIUM*		
	PLUMBUM		
	CUPRUM		
	HYDRARGYRUM		

*** Manganesium, cobaltium and nickel are frequently considered tetrads, whilst chromium is at times hexad, and stibium and bismuthum are sometimes pentad.**

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AIDS
TO
CHEMISTRY.

SPECIALLY DESIGNED FOR
STUDENTS PREPARING FOR EXAMINATION.

PART III.—ORGANIC.

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PREFACE.

BEARING in mind the number of excellent treatises upon Organic Chemistry already in existence, some apology may appear necessary for the appearance of the present volume; but the success which has attended the inorganic portions of these Aids has led me to hope that the following pages may not be altogether unacceptable.

In dealing with a science of such gigantic proportions as Organic Chemistry, it will be readily understood that in this short volume I have merely attempted an outline of the subject, and I can only hope that the extreme and recognised difficulties of the study may be taken as some extenuation for the unavoidable shortcomings of the following pages.

C. E. A. S.

8, TORRINGTON SQUARE, LONDON, W.C.
May, 1879.

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Alkaloids in which Carbon, Hydrogen, and Nitrogen are Contained. (*Conia*, *Nicotina*, *Piperidina*.)

Alkaloids in which Carbon, Hydrogen, Oxygen and Nitrogen are contained. (*Alkaloids of the Cinchonas, of Opium, of Strychnos; Theobromine; Theine, or Cafeine.*)

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ORGANIC CHEMISTRY.

THE term Organic Chemistry embraces the *Chemistry Of The Carbon Compounds,* and arose out of the fact of many of the compounds existing already formed in the bodies of plants and animals. It is separated from the Inorganic Portion, not on account of any absolute difference in the laws which regulate the formation of the substances classified in these two divisions, but in consequence of the enormous number of compounds included under Organic Chemistry, and the peculiar complications so frequently observed in their constitution.

Certain organic substances present a so-called *Organised Structure* which is directly and essentially the product of vegetable or animal life, and thus they, in this respect, vary entirely in their mode of formation and constitution from any inorganic compound. The simple cell, the generator of living organisms, exhibits this organised structure; it is impossible to prepare a cell artificially from its elements; but, on the other hand, many liquid or crystalline organic bodies may possibly be built up from their elementary constituents.

The number of carbon compounds already known is very remarkable, since they far exceed all the compounds of the other elements taken together, and every day is bringing new ones to light. Again, nearly all of them are formed by the union of different proportions of carbon with one or more of three other elements, viz., Oxygen, Hydrogen, and Nitrogen.

Carbon possesses in a remarkable degree the power of *Uniting With Itself* to form complex compounds containing an assemblage of carbon atoms combined with either oxygen, hydrogen, or nitrogen, or a number of these so joined together as to constitute a distinct chemical whole.

These atomic groups or *molecules* play an exactly similar part, in organic chemistry, to that of the metals, or simple molecules, as *PO, SO_2, NO_2, found in the Inorganic division; by them whole series of compounds are formed, in each of which it is possible to recognise the family likeness and to identify the group of atoms.

It will have been observed, in considering the non-metallic and metallic elements, that the substances included under these appellations possess different *atomicities*, or combining powers; *i.e.*, one atom of an element can replace, or combine with, one or more atoms of hydrogen in its combinations. Thus we have potassium, iodine, silver, etc., which can replace only *one* atom of hydrogen (the *monads*); oxygen, sulphur, copper, replacing *two* of hydrogen (the *dyads*); nitrogen, phosphorus, aluminium, replacing *three* of hydrogen (the *triads*); and we have seen that carbon is a tetrad, and marsh gas, $C\left\{\begin{matrix}H\\H\\H\\H\end{matrix}\right.$, was given in illustration of this property. This last-named substance is, in fact, the characteristic representative and *type* of *tetratomic* carbon.

In marsh gas it will be seen that carbon has *four combining units*, or *bonds*, thus, $-\overset{|}{\underset{|}{C}}-$, and that these are satisfied, or *saturated*, by being united with *four* atoms of hydrogen. This is therefore termed a SATURATED COMPOUND. But this condition can be satisfied by any other monad, and we may substitute one or more of the four atoms of hydrogen, step by step, by chlorine, forming the following SUBSTITUTION PRODUCTS. Thus:

Marsh gas; Methyl chloride; Methylene dichloride;

$$C\left\{\begin{matrix}H\\H\\H\\H\end{matrix}\right. ; \qquad C\left\{\begin{matrix}H\\H\\H\\Cl\end{matrix}\right. ; \qquad C\left\{\begin{matrix}H\\H\\Cl\\Cl\end{matrix}\right. ;$$

Chloroform; Carbon tetrachloride.

$$C\left\{\begin{matrix}H\\Cl\\Cl\\Cl\end{matrix}\right. ; \qquad C\left\{\begin{matrix}Cl\\Cl\\Cl\\Cl.\end{matrix}\right.$$

---

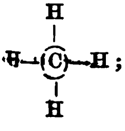
* See Appendix Part II.

But the four combining powers of carbon can also be satisfied by union with two dyad atoms, as in the cases of carbon dioxide, $C\left\{\begin{matrix}O\\O\end{matrix}\right.$, and carbon disulphide, $C\left\{\begin{matrix}S\\S\end{matrix}\right.$; or by one triad and one monad, as in prussic acid, $C\left\{\begin{matrix}N\\H.\end{matrix}\right.$

If two atoms of tetrad carbon unite one with another, a new group of atoms, or a *radical*, is formed. This is termed the *duplication* of the carbon element, and it comes about by *one* of the four combining units of one atom combining with *one* of the four units of the other atom. Thus, of the *eight* original combining units of the two carbon atoms, *two* are *saturated*, or got rid of, and *six* only remain free to enter into combination. The type of the mono-carbon series is CH_4; that of the di-carbon series is C_2H_6; that of the tri-carbon series is C_3H_8; that of the tetra-carbon series is C_4H_{10}; and no compound is known in any of these series just alluded to which contains respectively more than four, six, eight, or ten atoms of a monad.

On the other hand, certain groups of bodies exist in which all the combining powers of carbon are not fully satisfied. Thus we have C/O, carbonic monoxide, and C_2/H_4, olefiant gas. These are termed NON-SATURATED COMPOUNDS, and possess the power of directly uniting with other elements so as to fill up the combining powers that are vacant; for instance, CO and C_2H_4 both directly combine with two atoms of chlorine (Cl_2) forming saturated compounds, thus: $COCl_2$, carbonic oxychloride, and $C_2H_4Cl_2$, Dutch liquid, or ethylenic dichloride, in which all the carbon atoms are satisfied; but on the contrary, it is quite impossible to obtain any combination of chlorine with CO_2 or with C_2H_6. We may represent the combining powers of carbon in the following series:

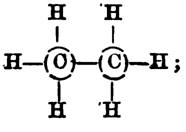
MONO-CARBON.



$$\begin{array}{ccc} & H & \\ & | & \\ H- & (C) & -H \\ & | & \\ & H & \end{array}$$

CH_4

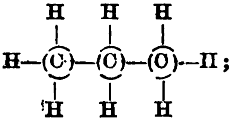
DI-CARBON.



$$\begin{array}{cccc} & H & H & \\ & | & | & \\ H- & (C)- & (C) & -H \\ & | & | & \\ & H & H & \end{array}$$

C_2H_6

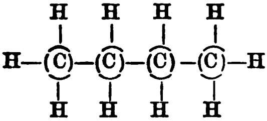
TRI-CARBON.



$$\begin{array}{ccccc} & H & H & H & \\ & | & | & | & \\ H- & (C)- & (C)- & (C) & -H \\ & | & | & | & \\ & H & H & H & \end{array}$$

C_3H_8

TETRA-CARBON.



C_4H_{10}.

The lines between the circles indicate the combinations of the carbon atoms one with another, and show how the compounds become saturated or satisfied. In each passage up the series it is therefore necessary to add *one* atom of carbon and *two* of hydrogen (CH_2), and this addition can actually be made by experiment.

Each carbon series may be considered to possess a group of atoms of carbon and hydrogen, to which the name of *compound radical* is given, and which takes exactly the same part in them as the metal does in the metallic salts of mineral chemistry.

In the above series, CH_4, C_2H_6, C_3H_8, C_4H_{10}, the radical is found to be a hydrocarbon containing one atom less hydrogen than the original type; each is therefore called a *Hydride* of a radical, and is looked upon as $\left.\begin{matrix}H\\H\end{matrix}\right\}$, in which a radical replaces one atom of hydrogen. Thus—

$$\left.\begin{matrix}CH_3\\H\end{matrix}\right\}\begin{matrix}\text{Methyl}\\\text{Hydride;}\end{matrix}\quad \left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}\begin{matrix}\text{Ethyl}\\\text{Hydride;}\end{matrix}\quad \left.\begin{matrix}C_3H_7\\H\end{matrix}\right\}\begin{matrix}\text{Propyl}\\\text{Hydride.}\end{matrix}$$

By replacing this atom of (hydride) hydrogen in these substances by either chlorine (Cl), bromine (Br), or iodine (I), we may obtain the corresponding chlorides, bromides, or iodides, respectively.

Again, if the same hydrogen be replaced by the monad radical HO, the bodies called *Alcohols* are obtained. Thus—

$$\left.\begin{matrix}CH_3\\HO\end{matrix}\right\}\begin{matrix}\text{Methyl}\\\text{Alcohol;}\end{matrix}\quad \left.\begin{matrix}C_2H_5\\HO\end{matrix}\right\}\begin{matrix}\text{Ethyl}\\\text{Alcohol;}\end{matrix}\quad \left.\begin{matrix}C_3H_7\\HO\end{matrix}\right\}\begin{matrix}\text{Propyl}\\\text{Alcohol.}\end{matrix}$$

The radicals CH_3, C_2H_5, C_3H_7, must be regarded as *absolutely indivisible*, and they *theoretically* act exactly the same part as a piece of potassium, sodium, or any other monad metal.

As has been shown in the Inorganic portion of Chemistry, we have radicals which may be *monobasic*, *dibasic*, *tribasic*, or *tetrabasic;* so with the carbon compounds we have radicals in which more than one combining power remains *unsaturated*, and which accordingly act as *polyatomic radicals*. Thus—*

Methyl, $\overset{I}{C}H_3$; Ethyl, $\overset{I}{C}_2H_5$; Propyl, $\overset{I}{C}_3H_7$, are monads.
Methylene, $\overset{II}{C}H_2$; Ethylene, $\overset{II}{C}_2H_4$; Propylene, $\overset{II}{C}_3H_6$, are dyads.
Methenyl, $\overset{III}{C}H$; Ethenyl, $\overset{III}{C}_2H_3$; Propenyl, $\overset{III}{C}_3H_5$, are triads.
Ethine, $\overset{IV}{C}_2H_2$; Propine, $\overset{IV}{C}_3H_4$, are tetrads.

A large number of derivatives take their origin from these bodies, in each of which is contained the radical, or group of hydrogen and carbon atoms. In whatever way the carbon atoms may be combined, the powers which remain unsaturated are an even number; it therefore follows that the sum of the atoms of monad or triad elements united with the carbon must be an even number, but the number of dyad elements is not subject to a similar restriction.

Organic substances, since their constitution is more complex, are more liable to decomposition and to transformation than the inorganic. The simple application of heat alone will produce many different results with them, varying according to the temperature to which each is exposed; thus, vapours, gases, ethereal, empyreumatic and oleaginous matters are procured; with chemical re-agents the products will be observed to be equally diversified.

Oxygen may act in four different ways upon an organic compound.

(1) By simple addition, viz.:

$$\begin{array}{ccccc} C_2H_4O & + & O & = & C_2H_4O_2 \\ \text{aldehyde} & + & \text{oxygen} & = & \text{acetic acid.} \end{array}$$

(2) By simple removal of hydrogen, viz.:

$$\begin{array}{ccccccc} C_2H_6O & + & O & = & H_2O & + & C_2H_4O \\ \text{alcohol} & + & \text{oxygen} & = & \text{water} & + & \text{aldehyde.} \end{array}$$

(3) By removal of hydrogen, and replacing it, 1 atom of oxygen replacing 2 of hydrogen, viz.:

$$\begin{array}{ccccccc} C_2H_6O & + & O_2 & = & H_2O & + & C_2H_4O_2. \\ \text{alcohol} & + & \text{oxygen} & = & \text{water} & + & \text{acetic acid.} \end{array}$$

(4) By removal of both hydrogen and carbon. It is thus that complicated organic bodies in which large numbers of hydrogen and carbon atoms are contained are reduced to others of simple constitution, the hydrogen and carbon being at last

---

* The signs I, II, III, IV, indicate the atomicity—monad, dyad, triad, or tetrad.

entirely converted into water (H_2O) and carbonic anhydride (CO_2).

Chlorine, bromine, and iodine act exactly in a similar manner as oxygen upon such bodies.

Nitric acid acts in various ways; sometimes it merely oxydises the compound, at other times it abstracts hydrogen and replaces it by nitryl (NO_2), or it sometimes unites directly with the compound as with a metal.

Alkalies may form a direct union with a substance, or they may abstract hydrogen from it and oxidise the product, and should it contain chlorine, may remove and appropriate it. Double decomposition may sometimes take place between the compound and the salt employed.

EMPIRICAL AND RATIONAL FORMULÆ.

CHEMICAL decompositions may be expressed either by ATOMIC or MOLECULAR formulæ; thus ($H + Cl = HCl$) is an atomic expression for hydrochloric acid, and ($H_2 + Cl_2 = 2HCl$) is its molecular expression. In the first reaction, a direct combination of the elements is assumed, and in the second the hydrogen is considered to replace the chlorine, or the reverse.

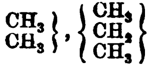
Two kinds of formulæ are made use of in the description of the composition of chemical bodies:

(1) THE EMPIRICAL.
(2) THE RATIONAL.

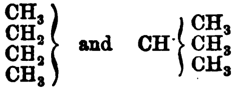
The EMPIRICAL simply shows the atomic composition of the molecule, as C_2H_6O (ordinary alcohol).

The RATIONAL does more than this, for it also points out its real character and its proper position in relation to other organic compounds; thus, the formula for alcohol is more properly C_2H_5HO, *i.e.*, hydroxide of ethyl. The *rational formula* is therefore to be preferred.

ISOMERISM.

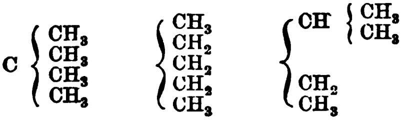
Carbon compounds are said to be ISOMERIC which possess the same percentage composition, but differ in their chemical and physical properties; thus, urea, CH_4N_2O, is termed isomeric with cyanate of ammonium, NH_4CNO. Of the series of hydrocarbons having the general formula C_nH_{2n+2}. The first three terms, CH_4.  $\left\{\begin{matrix}CH_3\\CH_3\end{matrix}\right\}$, $\left\{\begin{matrix}CH_3\\CH_2\\CH_3\end{matrix}\right\}$, have no isomers;

but the fourth, C_4H_{10}, is derived from the third by replacing an atom of hydrogen by the group CH_3; but this replacement may take place either with the carbon atoms at the end of the chain, or with the atom in the centre, and thus are obtained the following isomers—



$$\left.\begin{array}{l}CH_3\\CH_2\\CH_2\\CH_3\end{array}\right\}\text{ and }CH\left\{\begin{array}{l}CH_3\\CH_3\\CH_3\end{array}\right.$$

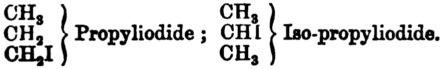
Of the fifth series, C_5H_{12}, there are three isomers, viz.:



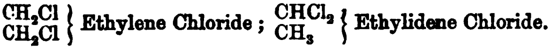
$$C\left\{\begin{array}{l}CH_3\\CH_3\\CH_3\\CH_3\end{array}\right.\qquad\left\{\begin{array}{l}CH_3\\CH_2\\CH_2\\CH_2\\CH_3\end{array}\right.\qquad\left\{\begin{array}{l}CH\left\{\begin{array}{l}CH_3\\CH_3\end{array}\right.\\ \\CH_2\\CH_3\end{array}\right.$$

As we pass to the higher members of the series there is a rapid increase of possible isomers.

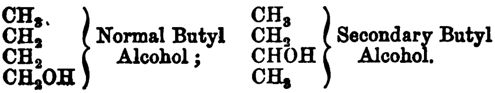
From these *hydrides* of the monad radicals, by the replacement of one or more hydrogen atoms by other elements or groups of atoms, the compounds of the *Paraffin Group* can be derived, and cases of isomerism will arise in accordance with this replacement taking place in connection with one or other of the carbon atoms. The following are simple examples:



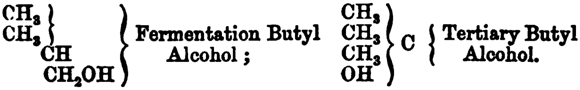
$$\left.\begin{array}{l}CH_3\\CH_2\\CH_2I\end{array}\right\}\text{ Propyliodide; }\left.\begin{array}{l}CH_3\\CHI\\CH_3\end{array}\right\}\text{ Iso-propyliodide.}$$



$$\left.\begin{array}{l}CH_2Cl\\CH_2Cl\end{array}\right\}\text{ Ethylene Chloride; }\left.\begin{array}{l}CHCl_2\\CH_3\end{array}\right\}\text{ Ethylidene Chloride.}$$



$$\left.\begin{array}{l}CH_3\\CH_2\\CH_2\\CH_2OH\end{array}\right\}\begin{array}{c}\text{Normal Butyl}\\\text{Alcohol;}\end{array}\quad\left.\begin{array}{l}CH_3\\CH_2\\CHOH\\CH_3\end{array}\right\}\begin{array}{c}\text{Secondary Butyl}\\\text{Alcohol.}\end{array}$$



$$\left.\begin{array}{l}\left.\begin{array}{l}CH_3\\CH_3\end{array}\right\}\\ \quad CH\\ \quad CH_2OH\end{array}\right\}\begin{array}{c}\text{Fermentation Butyl}\\\text{Alcohol;}\end{array}\quad\left.\begin{array}{l}CH_3\\CH_3\\CH_3\\OH\end{array}\right\}C\left\{\begin{array}{c}\text{Tertiary Butyl}\\\text{Alcohol.}\end{array}\right.$$

With the non-saturated compounds a much larger number of isomers is possible.

POLYMERISM.

Polymeric compounds are those which have the same percentage composition but different molecular weight.

The following substances containing twice as many hydrogen as carbon atoms are illustrations :

C_2H_4, Ethylene.
C_3H_6, Propylene.
C_4H_8, Butylene.
C_5H_{10}, Amylene.

METAMERISM.

Metameric bodies are those which have the same molecular weight and percentage composition, but are formed by different radicals which make up the same total number of atoms. The following are examples :

$\left.\begin{matrix}C_3H_7\\H\\H\end{matrix}\right\}$ N, Propylamine ; $\left.\begin{matrix}CH_3\\C_2H_5\\H\end{matrix}\right\}$ N, Methyl Ethylamine ;

$\left.\begin{matrix}CH_3\\CH_3\\CH_3\end{matrix}\right\}$ N, Trimethylamine.

$\left.\begin{matrix}C_3H_7\\C_3H_7\end{matrix}\right\}$ O, Dipropyl Ether ; $\left.\begin{matrix}CH_3\\C_5H_{11}\end{matrix}\right\}$ O, Methyl Amyl Ether ;

$\left.\begin{matrix}C_2H_5\\C_4H_9\end{matrix}\right\}$ O, Ethyl Butyl Ether.

$\left.\begin{matrix}C_4H_7O\\H\end{matrix}\right\}$ O, Butyric Acid ; $\left.\begin{matrix}CH_3\\C_3H_5O\end{matrix}\right\}$ O, Methyl Propionate ;

$\left.\begin{matrix}C_2H_5\\C_2H_3O\end{matrix}\right\}$ O, Ethyl Acetate ; $\left.\begin{matrix}C_3H_7\\CHO\end{matrix}\right\}$ O, Propyl Formate.

ORGANIC ANALYSIS.

To estimate the HYDROGEN AND CARBON:

When any compound of carbon and hydrogen is heated to redness in excess of oxygen, complete combustion takes place: oxidation of the carbon results, with the formation of carbonic anhydride (CO_2), whilst the hydrogen unites with oxygen to form water (H_2O). If, therefore, a given weight of such a compound be burnt, and the quantity of CO_2 and H_2O be weighed, the weight of carbon and of hydrogen contained in the substance can be ascertained.

The combustion of a *solid* organic substance is performed in a combustion tube, and can be made either in a current of oxygen or by mixing it with cupric oxide, CuO, which at a red heat readily parts with its oxygen to the carbon and hydrogen. In each case the products of the combustion are carefully collected and weighed.

The water produced in this operation is collected in a tube filled with pieces of *chloride of calcium*, by which aqueous vapour is entirely absorbed. The carbonic anhydride passes unabsorbed through the tube, and is received into a bulb-apparatus containing a strong solution of caustic potash.

The weights of the water and carbonic anhydride are respectively estimated by the increase in weight of the chloride of calcium tube and potash bulbs.

In analysing an organic *liquid*, this must be sealed up in a small weighed glass bulb drawn out to a fine point. After a second weighing the point is broken off, and the glass bulb is placed in the combustion tube, and the operation conducted as already indicated. Should nitrogen be present in the substance under analysis, copper turnings must be placed in the front part of the tube in order to decompose any nitrous fumes that may form and might be absorbed by the potash.

To determine the NITROGEN.

By heating nitrogenous organic bodies with caustic potash or soda, the whole of their contained nitrogen is given off in the form of ammonia. From this circumstance a given weight of the substance is heated in a tube with quicklime (CaO) and caustic soda ($NaHO$). Hydrochloric acid is added to the ammonia thus formed, and the weight of the ammonium chloride (NH_4Cl) produced is estimated as ammonio-platino-chloride by adding to it perchloride of platinum ($PtCl_5$). Every 100 parts by weight of ammonio-platino-chloride contain 6·33 parts of nitrogen.

When the nitrogen is contained as an oxide, the above method is inapplicable, since these oxides are not completely transformed into ammonia. The substance must then be heated with a mixture of mercury and copper oxides, and the produced gases passed over metallic copper. The nitrogen comes off as gas, and is purified by caustic soda from the carbonic anhydride evolved at the same time.

To estimate CHLORINE, SULPHUR, AND PHOSPHORUS.

Chlorine is determined by heating the compound to redness in a tube containing quicklime (CaO); chloride of calcium is formed, and to a solution of this in nitric acid nitrate of silver is added, the chlorine being weighed as chloride of silver.

To determine the *Sulphur and Phosphorus*, the organic body is heated in a tube with nitrate of potash and carbonate of soda. The *Sulphuric acid* may be estimated as sulphate of baryta after the addition of a soluble salt of barium, and the *Phosphoric acid* as ammonio-magnesian-phosphate by the addition of sulphate of magnesia and liquor ammoniæ.

The weight of OXYGEN is obtained by subtracting the sum of the weights of all the constituents that have been directly determined from the weight of the substance taken; *i.e.*, by difference.

DETERMINATION OF THE COMPOSITION, MOLECULAR WEIGHT AND FORMULA OF AN ORGANIC COMPOUND.

Having obtained the *relation*, we must next find the formula and molecular weight. Now, upon analysing 0·395 grammes of glacial acetic acid the following results are yielded: of carbonic anhydride 0·580 grammes, of water 0·235 grammes. Therefore, allowing for the oxygen, the amount of which is obtained by the difference, and calculating from the known atomic weights of C, H, and O, the following percentage composition is obtained.

100 parts of glacial acetic acid consist of—

Carbon	40·0
Hydrogen	6·6
Oxygen (by difference) ...	53·4
	100·0

If these numbers are respectively divided by the combining weights of C(=12), H(=1) and O(=16), thus—

$$\frac{40}{12} = 3{\cdot}3;\ \frac{6{\cdot}6}{1} = 6{\cdot}6;\ \frac{53{\cdot}4}{16} = 3{\cdot}3,$$

the relation of the constituents is obtained. The hydrogen atom is double of either the carbon atom or the oxygen atom; the constitution of acetic acid is therefore $C_nH_{2n}O_n$* ; but how are we to determine whether the correct formula is CH_2O, $C_2H_4O_2$, or $C_3H_6O_3$, or whether even a higher number of carbon atoms is contained? To determine this point, and therefore the molecular weight of the body, some compound of it with a well-known element, such as silver, for instance, must be found, in which one atom of silver replaces the atom of hydrogen in acetic acid; or rather, we must discover the weight of C, H, and O, in the ascertained relative proportion which forms a compound with one atom of silver. Now, only one such compound of acetic acid and silver exists, and by experiment it is found that 100 parts of acetate of silver contain 64·68 parts by weight of silver; consequently, the weight of carbon, hydrogen, and oxygen, combined with silver ($Ag = 108$) =

$$\frac{35{\cdot}32 \times 108}{64{\cdot}68} = 58{\cdot}98.$$

But in the acetate of silver one atom of hydrogen was replaced by silver, and therefore the molecular weight of the glacial acetic acid is found to be $58{\cdot}98 + 1 = 59{\cdot}98$, or its formula is—

$$\left.\begin{array}{l} C_2 = 24 \\ H_4 = 4 \\ O_2 = 32 \end{array}\right\} = C_2H_4O_2.$$
$$\overline{60}$$

This slight difference arises from the inevitable errors of experiment.

The molecular weights of organic bases are determined in a similar manner by ascertaining the weight of the substance which combines with a known weight of hydrochloric acid to form a salt.

THE DENSITY OR SPECIFIC GRAVITY OF THE VAPOURS OF VOLATILE ORGANIC BODIES.

The vapour volume of almost all volatile inorganic compounds is twice that occupied by the atom of hydrogen. To this law there are very few exceptions, and these may be explained by the fact of decomposition occurring when they are heated. The molecule of water, H_2O, weighing 18, occupies twice as large a volume as the atom of hydrogen, weighing 1, or the density of water-gas is 9.

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* By the co-efficient n is implied any number of atoms.

Hydrochloric acid, HCl, weighing 36·5, occupies two volumes, and its density is 18·75. Ammonia, NH_3, weighing 17, has a density of 8·5.

In organic chemistry the same simple relation is observed.

"*The molecule of every volatile organic compound occupies a volume twice as large as that occupied by an atom of hydrogen weighing* 1; *or the density of an organic compound is half its molecular weight.*"

The density of acetic acid vapour is experimentally found to be 30·07 ($H = 1$), and thus is observed a molecular weight to acetic acid of 60·14; and this agrees with the experiments above described. It is evident, therefore, that the experimental determination of the vapour densities of organic compounds is important as a means of controlling the correctness of the molecular weight found by the foregoing methods.

DRY OR DESTRUCTIVE DISTILLATION.

This operation consists in exposing organic bodies of simple constitution to a high but regulated temperature in a retort. By this means perfectly definite new compounds, together with carbonic anhydride and water, are often eliminated. By suddenly raising the heat to redness, the decomposition ceases to be regular, the watery vapour and carbonic anhydride give place to inflammable gases, such as hydrocarbons and carbonic oxide; tar and oily matters distil over, and at the end of the process the retort usually contains a residue of charcoal.

THE BOILING-POINT.

Under given circumstances of pressure, a constant and fixed boiling-point is observed in every volatile chemical compound. This fact is important in the determination of the purity of an organic liquid, and in the separation of the constituents of a mixture by the aid of continued or *Fractional Distillation.*

The boiling-points of the *homologous* series of chlorides, alcohols, hydrides, etc., rise with the increase of carbon, and very often in proportion to this increase, although no general law of connection between chemical composition and boiling point can be expressed.

The following is the method by which liquids boiling at different points are separated by means of

FRACTIONAL DISTILLATION.

The mixture is heated in a flask, from the top of which passes a bulb-tube, the large surface of which allows the vapour of the less volatile constituents to condense and return to the flask. A thermometer is placed in the bulb-tube and indicates the temperature. If this temperature rise beyond a given point, the liquid already distilled over is taken away, and an empty flask is supplied in its place to collect the next portion of fluid which comes over.

TYPICAL FORMULÆ.

THE CLASSIFICATION OF ORGANIC COMPOUNDS ACCORDING TO TYPES.

The majority of organic compounds may be arranged under the types of 1, 2, 3, or more atoms of water, and thus a remarkable analogy is presented between the carbon and the mineral compounds.*

All the *monatomic* alcohols having the formula $C_nH_{2n+2}O$ may be regarded as 1 molecule of water, $\left.\begin{matrix}H\\H\end{matrix}\right\}O$, in which 1 atom of hydrogen is replaced by a *monad radical,* the general formula of which is C_nH_{2n+1}; a series of *diatomic* alcohols exists with the general formula $C_nH_{2n+2}O_2$, or $(C_nH_{2n})''(OH)_2$, and are constructed upon the type of 2 molecules of water, $\left.\begin{matrix}H_2\\H_2\end{matrix}\right\}O_2$, in which 2 atoms of hydrogen are replaced by the *dyad* radical of the formula C_nH_{2n}, and lastly there is a series of *triatomic* alcohols of the general formula, $C_nH_{2n+2}O_3$, in which 3 molecules of water, $\left.\begin{matrix}H_3\\H_3\end{matrix}\right\}O_3$, are the type, and in which 3 atoms of hydrogen are replaced by a triatomic radical, C_nH_{2n-1}.

The type of the molecule of free hydrogen, namely, $\left.\begin{matrix}H\\H\end{matrix}\right\}$, is frequently employed in organic chemistry, of which illustrations are the chlorides and hydrides of the mono-, di-, and tri- carbon series previously noted. A third type upon which numerous organic compounds are constructed is the ammonia type, $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$. Examples of this have been observed in the inorganic section, viz., $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}P$, Phosphuretted hydrogen

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* See Appendix, Part II.

$\left.\begin{matrix}\mathrm{H}\\ \mathrm{H}\\ \mathrm{H}\end{matrix}\right\}\mathrm{Sb}$, Antimoniuretted hydrogen, $\left.\begin{matrix}\mathrm{H}\\ \mathrm{H}\\ \mathrm{H}\end{matrix}\right\}\mathrm{As}$, Arseniuretted hydrogen, etc.

A large number of compound ammonias will be noticed in the carbon compounds, all of them built upon the model of the simple inorganic ammonia, one or more atoms of hydrogen being replaced by organic radicals.

All organic compounds the constitution of which is understood, may be thus referred to one of the above-mentioned 3 great types, viz.,

$$\left.\begin{matrix}\mathrm{H}\\ \mathrm{H}\end{matrix}\right\}; \qquad \left.\begin{matrix}\mathrm{H}\\ \mathrm{H}\end{matrix}\right\}\mathrm{O}; \qquad \left.\begin{matrix}\mathrm{H}\\ \mathrm{H}\\ \mathrm{H}\end{matrix}\right\}\mathrm{N}.$$

Hydrogen type. Water type: Ammonia type.

All *Organic Compounds* may be arranged in the following twenty groups:

CLASS
I. Hydrocarbons, with an even number of hydrogen atoms.
II. Alcohols.
III. Haloid Ethers.
IV. Oxygen Ethers.
V. Mercaptans, or Sulphur Alcohols.
VI. Selenium Alcohols.
VII. Sulphur and Selenium Ethers.
VIII. Compound Ethers.
IX. Aldehydes.
X. Organic Acids.
XI. Acid Halides.
XII. Acid Oxides.
XIII. Ketones, or Acetones.
XIV. Amines.
XV. Alcoholic Ammonium Compounds.
XVI. Phosphorus, Arsenic, and Antimony Compounds resembling the two classes immediately preceding.
XVII. Organo-metallic Compounds not analogous to Ammonia or Ammonium Salts.
XVIII. Amides.
XIX. Amic Acids.
XX. Substances not included in the above groups.

GROUP I.—HYDROCARBONS, WITH AN EVEN NUMBER OF HYDROGEN ATOMS.

These are frequently considered to be hydrides of organic radicals, in which the numbers of hydrogen atoms are uneven; thus CH_4 may be regarded as CH_3H.

1st Series.—C_nH_{2n+2}. Paraffins. These are all saturated hydrocarbons, and receive this name since, by being saturated, they have no tendency to unite with other substances (*parum*, but little; *affinis*, related).

Sixteen of these have been prepared, containing from 1 to 16 atoms of carbon in each molecule. Many exist naturally in American and other mineral oils. They are the following:

Methane, CH_4.
Ethane, C_2H_6.
Propane, C_3H_8.
Quartane, C_4H_{10}.
Quintane, C_5H_{12}.
Sextane, C_6H_{14}.
Septane, C_7H_{16}.
Octane, C_8H_{18}.
Nonane, C_9H_{20}.
Decane, $C_{10}H_{22}$.
Undecane, $C_{11}H_{24}$.
Duodecane, $C_{12}H_{26}$.
Tridecane, $C_{13}H_{28}$.
Quatuordecane, $C_{14}H_{30}$.
Quindecane, $C_{15}H_{32}$.
Sexdecane, $C_{16}H_{34}$.

The first four are gaseous, the remainder liquids. They occur in nature, but may also be prepared artificially in the following modes:

(1) By acting upon alcoholic iodides with metallic zinc.

(2) By the dry distillation of cannel coal and boghead, etc.

2nd Series.—C_nH_{2n}. Olefines. These are thirteen in number, and are all exact multiples of CH_2, as follows:

Methene, CH_2.
Ethene, C_2H_4.
Propene, C_3H_6.
Quartene, C_4H_8.
Quintene, C_5H_{10}.
Sextene, C_6H_{12}.
Septene, C_7H_{14}.
Octene, C_8H_{16}.
Nonene, C_9H_{18}.
Decene, $C_{10}H_{20}$.
Sexdecene, $C_{16}H_{32}$.
Septivigintene, $C_{27}H_{54}$.
Trigintene, $C_{30}H_{60}$.

The lower compounds of this series are gaseous, the higher solid, and the intermediate liquid. They may be prepared by the decomposition of nascent paraffins, by the action of the metals sodium or zinc upon alcoholic iodides, or by decomposing butyrates or acetates at a red heat.

3rd Series.—C_nH_{2n-2}. There are only five of these procurable, viz.:

Ethine, C_2H_2.
Propine, C_3H_4.
Quartine, C_4H_6.
Quintine, C_5H_8.
Sextine, C_6H_{10}.

The first two are gaseous, the rest liquids; and they may be prepared by heating the bromides of the olefine derivatives with sodium ethylate.

4th Series.—C_nH_{2n-4}. Quintone, C_5H_6, is the only known compound of this series; but certain volatile oils, termed Terpenes, $C_{10}H_{16}$, found already formed in some plants, are included under this heading.

Quintone is a liquid prepared from an alcoholic solution of potash with quintine dibromide. *Terpenes* are chiefly found in plants of the orders Aurantiaceæ and Coniferæ. Amongst them are included the oils of turpentine, bergamot, lemon, orange, caraway, cloves, juniper, thyme, etc.

5th Series.—C_nH_{2n-6}. AROMATIC HYDROCARBONS. Only six have been prepared, viz.:

Benzene, C_6H_6.
Toluene, C_7H_8.
Xylene, C_8H_{10}.
Cumene, C_9H_{12}.
Cymene, $C_{10}H_{14}$.
Amylxylene, $C_{13}H_{20}$.

All except the last substance may be obtained by fractional distillation from the lighter oil formed by the destructive distillation of coal. They are all liquids.

6th Series.—C_nH_{2n-8}. Two only have been prepared, viz.:

Phenylene, C_6H_4; and Cinnamene, C_8H_8.

The latter is an oil existing in storax; but very little is known of the first.

7th Series.—C_nH_{2n-10}. Two of these only are supposed to have been separated, and they are as yet unnamed.

8th Series.—C_nH_{2n-12}. Naphthalene, $C_{10}H_8$ is the only one that has been procured, and this is unimportant.

9th Series.—C_nH_{2n-14}. The only known members of this series are, Diphenyl, $C_{12}H_{10}$, and Dibenzol, $C_{14}H_{14}$. Both are solids.

10th Series.—C_nH_{2n-16}. Stilbene, $C_{14}H_{12}$, is the only compound known. It occurs in mother-of-pearl-like plates.

11th Series.—C_nH_{2n-18}. Anthracene, $C_{14}H_{10}$. This is prepared by the dry distillation of coal. It occurs in small micaceous plates.

12th Series.—C_nH_{2n-24}. Chrysene, $C_{18}H_{12}$. This occurs in yellow crystalline plates, and is prepared by heating diphenyl in a tube with hydrogen.

The following formulæ show the general plan of formation of the hydrocarbons with an even number of carbon atoms. Thus—

1st Series.—	C_nH_{2n+2}.	7th Series.—	C_nH_{2n-10}.
2nd ,,	C_nH_{2n}.	8th ,,	C_nH_{2n-12}.
3rd ,,	C_nH_{2n-2}.	9th ,,	C_nH_{2n-14}.
4th ,,	C_nH_{2n-4}.	10th ,,	C_nH_{2n-16}.
5th ,,	C_nH_{2n-6}.	11th ,,	C_nH_{2n-18}.
6th ,,	C_nH_{2n-8}.	12th ,,	C_nH_{2n-24}.

The following table is a good illustration of these series; the first six, however, are only included with the names given them by Hofman, who has adopted the five vowels, a, e, i, o, u, the terminations being -ane, -ene, -ine, -one, -une, respectively. Thus—

1st Series. *Paraffins.*	2nd Series. *Olefines.*	3rd Series.	4th Series.	5th Series.	6th Series.	7th Series.
CH_4 Methane.	CH_2 Methene.					
C_2H_6 Ethane.	C_2H_4 Ethene.	C_2H_2 Ethine.				
C_3H_8 Propane.	C_3H_6 Propene.	C_3H_4 Propine.	C_3H_2 Propone.			
C_4H_{10} Quartane.	C_4H_8 Quartene.	C_4H_6 Quartine.	C_4H_4 Quartone.	C_4H_2 Quartune.		
C_5H_{12} Quintane.	C_5H_{10} Quintene.	C_5H_8 Quintine.	C_5H_6 Quintone.	C_5H_4 Quintune.	C_5H_2.	
C_6H_{14} Sextane.	C_6H_{12} Sextene.	C_6H_{10} Sextine.	C_6H_8 Sextone.	C_6H_6 Sextune.	C_6H_4.	C_6H_2.

If this table be read from above downwards, an *Homologous* series is presented, each differing from the one immediately above or below it by CH_2; if read from left to right, an *Isologous* series appears, each molecule possessing H_2 less than the one preceding.

From this it is obvious that a *saturated hydrocarbon* may be deprived of one or more atoms of hydrogen, and produce new homologous series; thus methane, CH_4, may become CH_2 (methene); ethane, C_2H_6, become C_2H_4 (ethene); propane, C_3H_8, may form C_3H_6 (propene), etc. These new substances are therefore molecules of *unsaturated hydrocarbons*, having two bonds uncombined and free, and consequently acting as *dyads*. Again, C_2H_4, C_3H_6, and C_4H_8 may by suitable means lose a second molecule of hydrogen; and other series are developed, viz.: C_2H_2 (ethine), C_3H_4 (propine), etc., each being *quadrivalent* or *tetrad*, since they present *four* bonds unsatisfied and free.

It has been previously shown that a saturated hydrocarbon may yield up one or more atoms of its hydrogen to another element. Thus from methane, CH_4, we may obtain CH_3Cl, CH_2Cl_2, $CHCl_3$, and CCl_4; these *substitution products* may be considered as formed of Chlorine (Cl) with radicals, CH_3 (monad), CH_2 (dyad), CH (triad), and C (tetrad), respectively; *the quantivalence depending altogether upon the number of hydrogen atoms abstracted from the original saturated molecule.*

The substances of *even* quantivalence, *dyads* and *tetrads*, contain *even* numbers of hydrogen atoms, but those, the quantivalence of which is *uneven*, viz.: *monads*, *triads* and *pentads*, contain *odd* numbers of hydrogen atoms, and are regarded as *double molecules;* the termination *yl* is applied to these latter, viz.: methyl, $(CH_3)_2$; ethyl, $(C_2H_5)_2$; propyl, $(C_3H_7)_2$, etc.

CH_4 Methane.	$\overset{\text{I}}{(CH_3)}$ Methyl.	$\overset{\text{II}}{(CH_2)}$ Methene.	$\overset{\text{III}}{(CH)}$ Methenyl.				
C_2H_6 Ethane.	$\overset{\text{I}}{(C_2H_5)}$ Ethyl.	$\overset{\text{II}}{(C_2H_4)}$ Ethene.	$\overset{\text{III}}{(C_2H_3)}$ Ethenyl.	$\overset{\text{IV}}{(C_2H_2)}$ Ethine.	$\overset{\text{V}^*}{(C_2H)}$ Ethinyl.		
C_3H_8 Propane.	$\overset{\text{I}}{(C_3H_7)}$ Propyl.	$\overset{\text{II}}{(C_3H_6)}$ Propene.	$\overset{\text{III}}{(C_3H_5)}$ Propenyl.	$\overset{\text{IV}}{(C_3H_4)}$ Propine.	$\overset{\text{V}}{(C_3H_3)}$ Propinyl.	$\overset{\text{VI}}{(C_3H_2)}$ Propone.	$\overset{\text{VII}}{(C_3H)}$ Proponyl.

The succeeding table indicates the various substances constructed upon the compound radicals, CH_3 (methyl); C_2H_5, (ethyl); C_3H_7 (propyl), etc. These radicals are all *monads*, *i.e.*, can only replace one atom of hydrogen.

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* The indices V, VI, VII indicate pentad, hexad, heptad.

COMPOUND RADICALS.		SATURATED HYDROCARBONS. HYDRIDES *Formulæ.*		OXIDES OR ETHERS.	HYDROXIDES OR ALCOHOLS.	ALDEHYDES.	ACIDS.		
		Empirical.	*Rational.*						
Methyl	CH_3	CH_4 or	CH_3H	$(CH_3)_2O$	CH_3HO	CH_2O	CH_2O_2	Formic	Acid.
Ethyl	C_2H_5	C_2H_6 or	C_2H_5H	$(C_2H_5)_2O$	C_2H_5HO	C_2H_4O	$C_2H_4O_2$	Acetic	,,
Propyl	C_3H_7	C_3H_8 or	C_3H_7H	$(C_3H_7)_2O$	C_3H_7HO	C_3H_6O	$C_3H_6O_2$	Propianic	,,
Butyl	C_4H_9	C_4H_{10} or	C_4H_9H	$(C_4H_9)_2O$	C_4H_9HO	C_4H_8O	$C_4H_8O_2$	Butylic	,,
Amyl	C_5H_{11}	C_5H_{12} or	$C_5H_{11}H$	$(C_5H_{11})_2O$	$C_5H_{11}HO$	$C_5H_{10}O$	$C_5H_{10}O_2$	Valerianic	,,
Hexyl	C_6H_{13}	C_6H_{14} or	$C_6H_{13}H$	$(C_6H_{13})_2O$	$C_6H_{13}HO$	$C_6H_{12}O$	$C_6H_{12}O_2$	Caproic	,,
Heptyl	C_7H_{15}	C_7H_{16} or	$C_7H_{15}H$	$(C_7H_{15})_2O$	$C_7H_{15}HO$	$C_7H_{14}O$	$C_7H_{14}O_2$	Œnanthylic	,,
Octyl	C_8H_{17}	C_8H_{18} or	$C_8H_{17}H$	$(C_8H_{17})_2O$	$C_8H_{17}HO$	$C_8H_{16}O$	$C_8H_{16}O_2$	Capric	,,
Nonyl	C_9H_{19}	C_9H_{20} or	$C_9H_{19}H$	$(C_9H_{19})_2O$	$C_9H_{19}HO$	—	$C_9H_{18}O_2$	Pelargonic	,,
Decatyl	$C_{10}H_{21}$	$C_{10}H_{22}$ or	$C_{10}H_{21}H$	$(C_{10}H_{21})_2O$	$C_{10}H_{21}HO$	—	$C_{10}H_{20}O_2$	Rutic	,,
Undecyl	$C_{11}H_{23}$	$C_{11}H_{24}$ or	$C_{11}H_{23}H$	$(C_{11}H_{23})_2O$	$C_{11}H_{23}HO$	$C_{11}H_{22}O$	$C_{11}H_{22}O_2$	—	
Duodecyl ...	$C_{12}H_{25}$	$C_{12}H_{26}$ or	$C_{12}H_{25}H$	$(C_{12}H_{25})_2O$	$C_{12}H_{25}HO$	—	$C_{12}H_{24}O_2$	Lauric	,,
Tridecyl	$C_{13}H_{27}$	$C_{13}H_{28}$ or	$C_{13}H_{27}H$	$(C_{13}H_{27})_2O$	$C_{13}H_{27}HO$	—	—	—	
Quatuordecyl	$C_{14}H_{29}$	$C_{14}H_{30}$ or	$C_{14}H_{29}H$	$(C_{14}H_{29})_2O$	$C_{14}H_{29}HO$	—	$C_{14}H_{28}O_2$	Myristic	,,
Quindecyl ...	$C_{15}H_{31}$	$C_{15}H_{32}$ or	$C_{15}H_{31}H$	$(C_{15}H_{31})_2O$	$C_{15}H_{31}HO$	—	—	—	
Cetyl	$C_{16}H_{33}$	$C_{16}H_{34}$ or	$C_{16}H_{33}H$	$(C_{16}H_{33})_2O$	$C_{16}H_{33}HO$	—	$C_{16}H_{32}O_2$	Palmitic	,,
—	—	—		—	—	—	$C_{17}H_{34}O_2$	Margaric	,,
—	—	—		—	—	—	$C_{18}H_{36}O_2$	Stearic	,,
—	—	—		—	—	—	$C_{20}H_{40}O_2$	Arachnic	,,
—	—	—		—	—	—	$C_{22}H_{44}O_2$	Behenic	,,
Ceryl	$C_{27}H_{55}$	—		—	$C_{27}H_{55}HO$	—	$C_{27}H_{54}O_2$	Cerotic	,,
Meryl	$C_{30}H_{61}$	—		—	$C_{30}H_{61}HO$	—	$C_{30}H_{60}O_2$	Melissic	,,

The vacancies indicate that such compounds have not as yet been isolated. It will be observed that the *Saturated Hydrocarbons* are regarded as *Hydrides* of the *Compound Radicals*; the *Oxides* are known as *Ethers*, the *Hydroxides* as *Alcohols*; their compounds with *Acetic Acid* and other *Acids* are called *Ethereal Salts*; each furnishes an *Aldehyde*, and one or more *Acids*.

In the preceding table, if R represent the radical, it will appear that the *Hydride* of each series is formed by the addition of H to the radical, thus, RH; the *Oxide*, or *Ether*, is formed by doubling the radical and adding O, thus, $R_2 + O$. The *Alcohol* will be formed by adding HO to the radical, thus, R + HO; the *Aldehyde*, by abstracting H from the radical and adding O, thus, $(R-H) + O$; and the *Acid*, by abstracting H from the radical and adding O_2, thus, $(R-H) + O_2$. For example let us take the ethyl series. Thus—

R (radical).	RH.	$(R)_2O$.	RHO.	$(R-H)+O$.	$(R-H)+O_2$.
Ethyl.	Hydride.	Ether.	Alcohol.	Aldehyde.	Acid(acetic).
C_2H_5.	C_2H_5H.	$(C_2H_5)_2O$.	C_2H_5HO.	C_2H_4O.	$C_2H_4O_2$.

And so through all the different series.

GROUP II.—ALCOHOLS.

These organic compounds are composed of hydrocarbon radicals (therefore termed alcohol radicals) combined with hydroxyl (HO).

The term alcohol, although at one time exclusively applied to spirits of wine, is now employed to designate a large class of organic compounds, differing greatly from each other in their properties and appearance, but resembling each other in being all *saturated hydrocarbons*, in which one or more of the hydrogen atoms have been replaced by hydroxyl (HO). Since these radicals differ in their quantivalence, we may have *Monatomic*, *Diatomic*, *Triatomic*, and *Polyatomic* Alcohols, in accordance with the number of hydroxyl (HO) molecules contained; thus, from propene, C_3H_8, may be prepared three alcohols: the Monatomic Propyl Alcohol $(C_3H_7)^I(HO)$; the Diatomic Propene Alcohol $(C_3H_6)^{II}(HO)_2$; and the Triatomic Propene Alcohol $(C_2H_5)^{III}(HO)_3$.

Alcohols are divisible into *Primary*, *Secondary*, *or Tertiary*, according as the carbon atom which is combined with the hydroxyl is at the same time united with one, two, or three other carbon atoms. Thus—

$$\begin{array}{ccc} \text{Primary.} & \text{Secondary.} & \text{Tertiary.} \\ C\begin{cases} CH_2,\ CH_2,\ CH_3 \\ H \\ H \\ HO \end{cases}; & C\begin{cases} CH_2,\ CH_3 \\ CH_3 \\ H \\ HO \end{cases}; & C\begin{cases} CH_3 \\ CH_3 \\ CH_3 \\ HO \end{cases} \end{array}$$

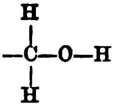
These alcohols differ from one another in a remarkable degree; and this difference is particularly noticeable when they are subjected to the action of oxidising agents. They then undergo the following changes :

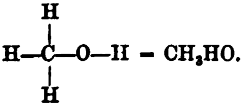
[*]*Primary Alcohols* are converted first into aldehydes, and then into acids containing the same number of carbon atoms.

Secondary Alcohols are converted into acetones, which, upon further oxidation, yield acids with a smaller number of carbon atoms.

Tertiary Alcohols are decomposed without previous formation of aldehydes or acetones, yielding acids with a smaller number of carbon atoms.

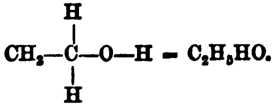
PRIMARY ALCOHOLS.

In all of these, the group, $CH_2.OH$, or  $\begin{array}{c}\mathrm{H}\\|\\\mathrm{—C—O—H}\\|\\\mathrm{H}\end{array}$ is present, as may be observed in methyl alcohol, which is a compound of this group with hydrogen. Thus—

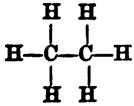


$$\begin{array}{c}\mathrm{H}\\|\\\mathrm{H—C—O—H}\\|\\\mathrm{H}\end{array} = CH_3HO.$$

In ethyl alcohol this group is also present. Thus—



$$\begin{array}{c}\mathrm{H}\\|\\\mathrm{CH_3—C—O—H}\\|\\\mathrm{H}\end{array} = C_2H_5HO.$$

In the compound  $\begin{array}{c}\mathrm{H\ \ H}\\|\ \ \ |\\\mathrm{H—C—C—H}\\|\ \ \ |\\\mathrm{H\ \ H}\end{array}$ it matters not which atom of hydrogen is replaced by hydroxyl (OH), since the resulting compound will always have the same constitution, and will necessarily contain the group $CH_2.OH$.

All primary alcohols are derived from methyl alcohol by replacing a hydrogen atom with hydrocarbon radicals of various constitution and composition ; thus, in this alcohol,

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[*] Ira Remsen : "Principles of Theoretical Chemistry."

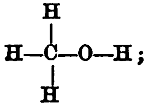
By the replacement of a hydrogen atom by methyl, CH_3, we obtain ethyl alcohol, CH_3,CH_2,OH.

By the replacement of a hydrogen atom by ethyl, C_2H_5, we obtain propyl alcohol, C_2H_5,CH_2,OH.

By the replacement of a hydrogen atom by propyl, C_3H_7, we obtain butyl alcohol, C_3H_7,CH_2,OH.

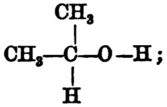
SECONDARY ALCOHOLS.

By replacing two hydrogen atoms of methyl alcohol with hydrocarbon radicals, alcohols are obtained in which the group $CH_2.OH$ is not contained. Thus—



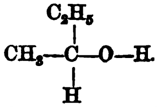
$H-\underset{H}{\overset{H}{C}}-O-H$;

Methyl Alcohol.



$CH_3-\underset{H}{\overset{CH_3}{C}}-O-H$;

Isopropyl Alcohol.



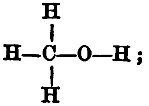
$CH_3-\underset{H}{\overset{C_2H_5}{C}}-O-H$.

Secondary Butyl Alcohol.

Here the group $CH.OH$ is present, and these bodies represent the secondary alcohols, the simplest example of which is the substance given above, viz.: Isopropyl Alcohol, C_3H_8O.

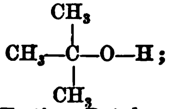
TERTIARY ALCOHOLS.

By the replacement of three hydrogen atoms of methyl alcohol by hydrocarbon radicals, we obtain alcohols possessing neither the group $CH_2.OH$, nor the group $CH.OH$. Thus—



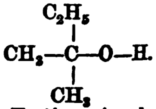
$H-\underset{H}{\overset{H}{C}}-O-H$;

Methyl Alcohol.



$CH_3-\underset{CH_3}{\overset{CH_3}{C}}-O-H$;

Tertiary Butyl Alcohol.



$CH_3-\underset{CH_3}{\overset{C_2H_5}{C}}-O-H$.

Tertiary Amyl Alcohol.

These bodies represent the tertiary alcohols, and in them the group $C.O.H$ is contained.

The simplest example is the tertiary butyl alcohol, $C_4H_{10}O$, given above.

GROUP III.—HALOID ETHERS.

This name is applied to the compounds of hydrocarbon radicals with the halogens chlorine, bromine, iodine, viz.:

Methyl Chloride, CH_3Cl; Ethyl Chloride, $(C_2H_5)^{I}Cl$; Ethene Bromide, $(C_2H_4)^{II}Br_2$; Propenyl Iodide, $(C_3H_5)^{III}I_3$.

GROUP IV.—OXYGEN ETHERS, OR ALCOHOLIC OXIDES.

These are compounds of oxygen with the hydrocarbon radicals, viz.: Ethyl Oxide, $(C_2H_5)^{I}{}_2O$; Ethene Oxide, $(C_2H_4)^{II}O$.

GROUP V.—MERCAPTANS,* OR SULPHUR ALCOHOLS.

These substances may be regarded as alcohols in which the O of the HO is replaced by sulphur (S); thus Methyl Alcohol is CH_3HO; Methyl Mercaptan, or Methyl Hydrosulphide, is CH_3HS.

Ethyl Alcohol is C_2H_5HO; Ethyl Mercaptan, or Ethyl Hydrosulphide, is C_2H_5HS.

GROUP VI.—SELENIUM ALCOHOLS.

These compounds are analogous to the mercaptans, Selenium (Se) being substituted for the Sulphur (S). Thus—Methyl Mercaptan, CH_3HS; Methyl Selenium Alcohol, CH_3HSe.

GROUP VII.—SULPHUR AND SELENIUM ETHERS

Are similar to the oxygen ethers, S and Se replacing the oxygen in those substances.

GROUP VIII.—COMPOUND ETHERS, OR ETHEREAL SALTS.

These are formed by substituting an alcohol radical for an atom of hydrogen (H) in an acid, exactly as an ordinary metallic salt is formed. Thus, H_2SO_4 = Sulphuric Acid; $(C_2H_5)_2HSO_4$ = Monethyl Sulphate; $(C_2H_5)_2SO_4$ = Diethyl Sulphate.

GLUCOSIDES is the term applied to certain vegetable principles which, when boiled with a dilute acid, yield *glucose;* these substances are considered to be compound ethers of the alcohols. They are the following:

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* Corpora mercurio apta, *i.e.*, bodies readily uniting with mercury.

1.	Æsculin *	$C_{21}H_{24}O_{13}$	from Horsechestnuts.
2.	Amygdalin	$C_{20}H_{27}NO_{11}, 3H_2O$	from Almonds.
3.	Cathartic Acid	$C_{180}H_{192}N_4SO_{82}$	from Senna.
4.	Chitin	$C_9H_{15}NO_6$	from Insects.
5.	Colocynthin	$C_{56}H_{84}O_{23}$	from Bitter apple.
6.	Gallotannin	$C_{27}H_{22}O_{17}$	from Nut-galls.
7.	Convolvulin	$C_{34}H_{56}O_{16}$	from Jalap.
8.	Glycyrrhizin	$C_{24}H_{36}O_9$	from Liquorice.
9.	Digitalin	$C_{27}H_{45}O_{15}$	from Foxglove.
10.	Phlorizin	$C_{21}H_{24}O_{10}2H_2O$	from Apple-tree bark.
11.	Salicin	$C_{13}H_{18}O_7$	from Poplars & Willows.
12.	Elaterin	$C_{20}H_{28}O_5$	from Squirting cucumbers.
13.	Helicin	$C_{13}H_{16}O_7$	from Salicin and nitric acid.
14.	Guaiacin	$C_{20}H_{23}O_5$?	from Lignum Vitæ.
15.	Thujin	$C_{20}H_{22}O_{12}$	from Arbor Vitæ.
16.	Jalapin	$C_{31}H_{50}O_{16}$	from Jalap.
17.	Myronic Acid	$C_{10}H_{19}NS_2O_{10}$	from Mustard.
18.	Santonin	$C_{16}H_{18}O_3$	from Santonica.
19.	Quercitrin	$C_{33}H_{30}O_{17}$	from Gall-oak.
20.	Scammonin	$C_{32}H_{52}O_{16}$	from Scammony.
21.	Populin	$C_{20}H_{22}O_8$	from the Aspen.
22.	Saponin	$C_{12}H_{20}O_7$	from Soap-Wort.
23.	Solanin	$C_{43}H_{71}NO_{16}$	from Bittersweet.
24.	Arbutin	$C_{12}H_{16}O_7$	from Bearberry.
25.	Xanthorhamnin	$C_{23}H_{28}O_{14}$	from Buckthorn.

GROUP IX.—ALDEHYDES.

These compounds are produced by the oxidation of alcohols, hydrogen being removed. Thus—

$$C_2H_6O + O = H_2O + C_2H_4O.$$

Ethyl alcohol and oxygen yield water and aldehyde.

Aldehydes readily decompose, undergoing further oxidation by absorbing oxygen from the air, and are converted into organic acids. Thus—

$$C_2H_4O + O = C_2H_4O_2.$$

Aldehyde and oxygen yield acetic acid.

By the addition of nascent hydrogen, aldehydes may be reconverted into alcohols.

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* Kollmyer.

The ALDEHYDES are the following :—

Formic Aldehyde	...	CH_2O	Acrylic Aldehyde	...	C_3H_4O
Acetic ,,	...	C_2H_4O	Benzoic ,,	...	C_7H_6O
Propianic ,,	...	C_3H_6O	Toluic ,,	...	C_8H_8O
Butylic ,,	...	C_4H_8O	Cumic ,,	...	$C_{10}H_{12}O$
Valerianic ,,	...	$C_5H_{10}O$	Sycocerylic ,,	...	$C_{18}H_{28}O$
Caproic ,,	...	$C_6H_{12}O$	Cinnamic ,,	...	C_9H_8O
Œnanthylic ,,	...	$C_7H_{14}O$	Salicylic ,,	...	$C_7H_6O_2$
Capric ,,	...	$C_8H_{16}O$	Anisic ,,	...	$C_8H_8O_2$
Euodic Aldehyde	...	$C_{11}H_{22}O$			

The GLUCOSES may be regarded as Aldehydes of Alcohols. They are all composed of $C_6H_{12}O_6$, and are the following :—

1. Ordinary Glucose, or grape sugar.
2. Levulose from cane sugar and nitric acid.
3. Maltose from malt.
4. Mannitose from mannite.
5. Galactose from milk-sugar, by the addition of an acid.
6. Inosite from flesh of animals.
7. Sorbite from red-ash berries.
8. Eucolyn from Australian manna.

A POLYGLUCOSIC ALCOHOL is a substance containing less oxygen and hydrogen than the molecules of glucose from which it is supposed to be formed. Thus—

$$2C_6H_{12}O_6 - H_2O = C_{12}H_{22}O_{11}.$$

Glucose – Water = Diglucosic Alcohol (Ordinary Cane Sugar).

This series includes *Starch*, $C_6H_{10}O_5$, or more probably $C_{18}H_{30}O_{15}$, and *Dextrine ;* the latter is made by boiling starch with sulphuric acid, or with *Diastase*, a substance existing only in germinating grain. The starch takes up a molecule of water (H_2O). Thus—

$$C_{18}H_{30}O_{15} + H_2O = C_6H_{12}O_6 + 2C_6H_{10}O_5.$$

Starch and water yield glucose and dextrine.

Cellulose and lignin from plants have the same composition as starch, and are both convertible into grape-sugar.

Glycogen, $C_6H_{10}O_5$, is a principle found in the liver of animals : it is not fermentable, and may be converted into glucose by the action of the blood, the pancreatic and salivary secretions, or by boiling with *Diastase* or a dilute acid.

GROUP X.—ORGANIC ACIDS.

These may be considered as compounds of the oxygenated radicals with hydroxyl (HO), and may be formed from the alcohols by substituting O for H_2. Thus—

$$\text{Alcohol, } C_2H_6O + 2O = H_2O + C_2H_4O_2 = C_2H_3OHO \text{ or Acetic acid.}$$

An alcohol may give rise to one or many acids, the number of which may be accurately ascertained by discovering how often the group CH_2HO is possible of formation from its molecule, since the production of the acid is due to the substitution of an atom of oxygen (O) for the two atoms of hydrogen (H_2) in this group, an acid radical, OXATYL (COHO), resulting; for instance, Ethene Alcohol, $C_2H_6O_2$, is equal to $2CH_2HO$, and by the oxidation of this GLYCOLLIC ACID, $C_2H_4O_3$, or $CH_2HO,COHO$, is produced, which, upon further oxidation, yields OXALIC ACID, $C_2H_2O_4$, or $COHO,COHO$, in accordance with the removal of H_2 or $2H_2$, and the substitution of O or O_2 for the displaced H.

Again, the basic power of the acid depends upon the number of molecules of oxatyl which are contained in it, *i.e.*, upon the number of hydrogen molecules which have been taken from the original alcohol, and have been replaced by a corresponding amount of oxygen.

GROUP XI.—ACID HALIDES.

These are compounds of the organic acids with the halogens chlorine, iodine, and bromine, and are defined as compounds of acid or oxygenated radicals with chlorine, iodine and bromine; thus, C_2H_3OCl is Acetyl Chloride; C_2H_2OBr, Acetyl Bromide.

GROUP XII.—ACID OXIDES, ANHYDROUS ACIDS, AND ANHYDRIDES.

These bear the same relation to the acids as the oxygen ethers of alcoholic oxides do to the alcohols; thus, C_2H_5HO = Ethyl Alcohol; $(C_2H_5)_2O$ = Ethyl Ether; and C_2H_3OHO = Acetic Acid; whilst $(C_2H_3O)_2O$ = Acetic Oxide.

GROUP XIII.—KETONES OR ACETONES.

This term is applied to those substances which are derived from Aldehydes by the substitution of an *Alcohol Radical* for an atom of H in a group of its atoms of COH; thus, *Acetic Aldehyde*, CH_3COH, forms *Acetone*, CH_3COCH_3.

GROUP XIV.—AMINES. COMPOUND AMMONIAS.

These substances are produced by substituting an alcohol radical for the H in the type *Ammonia*, $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$. They are termed Monamines, Diamines, Triamines, etc., since one or more molecules of ammonia, *i.e.*, $NH_3, 2NH_3, 3NH_3, 4NH_3$, may engage in their formation. They are likewise termed Primary, Secondary, or Tertiary, according as the radical replaces one or more of the hydrogen atoms.

Each hydrogen atom is not necessarily replaced by the same radical; but these may all differ as follows:—

Ammonia.	Methylamine.	Dimethylamine.	Trimethylamine.	Dimethyl-Ethylamine.	Methyl-Ethyl-Amylamine.
$\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$;	$\left.\begin{matrix}CH_3\\H\\H\end{matrix}\right\}N$;	$\left.\begin{matrix}CH_3\\CH_3\\H\end{matrix}\right\}N$;	$\left.\begin{matrix}CH_3\\CH_3\\CH_3\end{matrix}\right\}N$;	$\left.\begin{matrix}CH_3\\CH_3\\C_2H_5\end{matrix}\right\}N$;	$\left.\begin{matrix}CH_3\\C_2H_5\\C_5H_{11}\end{matrix}\right\}N$.

Since the AMINES are regarded as compounds of alcohol radicals with $(NH_2)^I$ Amidogen, $(NH)^{II}$ Imidogen, and $(N)^{III}$ triad Nitrogen, they are often termed ALCOHOL BASES. Salts are formed by the union of these compounds with acids.

NITRILES is the name given to those substances in which the H is entirely replaced by radicals.

This group includes the vegetable alkaloids, since they are all apparently substitution-products of ammonia. Amongst them may be mentioned Aconitia, Atropia, Brucia, Cinchonine, Codeia, Conia, Hyoscyamia, Meconine, Morphia, Physostigmine (Eserine), Quinia, Strychnia, Veratria, etc.

GROUP XV.—ALCOHOLIC AMMONIUM COMPOUNDS.

These substances contain Pentad Nitrogen *(N^v) combined with H, which, however, is always to a certain extent replaced by alcohol radicals, viz.:

Ethylammonium Chloride.	Diethylammonium Chloride.	Tri-ethylammonium Chloride.
$\left.\begin{matrix}C_2H_5\\H\\H\\H\\Cl\end{matrix}\right\}N^v.$	$\left.\begin{matrix}C_2H_5\\C_2H_5\\H\\H\\Cl\end{matrix}\right\}N^v.$	$\left.\begin{matrix}C_2H_5\\C_2H_5\\C_2H_5\\H\\Cl\end{matrix}\right\}N^v.$

Tetra-ethylammonium Chloride.	Tetrethylammonium Hydrylate.
$\left.\begin{matrix}C_2H_5\\C_2H_5\\C_2H_5\\C_2H_5\\Cl\end{matrix}\right\}N^v.$	$\left.\begin{matrix}C_2H_5\\C_2H_5\\C_2H_5\\C_2H_5\\HO\end{matrix}\right\}N^v.$

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* Nitrogen is usually *triad*, but often *pentad*, as here observed.

GROUP XVI.—ARSENIC, PHOSPHORUS AND ANTIMONY COMPOUNDS.

These are termed **Arsines, Phosphines, Stibines.** They are analogous to the nitrogen compounds in Groups XIV. and XV. The metals apparently replace the nitrogen (both as triad and pentad) in ammonia.

Triethyl Arsine.

$$\left.\begin{matrix} C_2H_5 \\ C_2H_5 \\ C_2H_5 \end{matrix}\right\} As^{III}.$$

Methyl-Triethyl Arsonium Chloride.

$$\left.\begin{matrix} CH_3 \\ C_2H_5 \\ C_2H_5 \\ C_2H_5 \\ Cl \end{matrix}\right\} As^{V}.$$

Triethyl Phosphine.

$$\left.\begin{matrix} C_2H_5 \\ C_2H_5 \\ C_2H_5 \end{matrix}\right\} P^{III}.$$

Tetramethyl-phosphonium Chloride.

$$\left.\begin{matrix} CH_3 \\ CH_3 \\ CH_3 \\ CH_3 \\ Cl \end{matrix}\right\} P^{V}.$$

Triethyl Stibine.

$$\left.\begin{matrix} C_2H_5 \\ C_2H_5 \\ C_2H_5 \end{matrix}\right\} Sb^{III}.$$

Tetrethyl Stibonium Hydrylate.

$$\left.\begin{matrix} C_2H_5 \\ C_2H_5 \\ C_2H_5 \\ C_2H_5 \\ HO \end{matrix}\right\} Sb^{V}.$$

GROUP XVII.—ORGANO-METALLIC COMPOUNDS.

This group includes the compounds formed by metals with organic radicals, such as Methyl, Ethyl, Amyl, etc., viz.: Aluminium Methyl, $Al(CH_3)_3$, and Zinc Ethyl, $Zn(C_2H_5)_2$.

GROUP XVIII.—AMIDES.

These substances are similar in composition to the Amines, except that they form their compounds with *Acid-radicals* which replace the Hydrogen of Ammonia, and not that of the alcohol radicals.

Amides may be *monatomic*, *diatomic*, or *triatomic;* and *primary*, *secondary*, or *tertiary*. When these contain *Imidogen* (NH^{II}), united with dyad acid radicals, they are called **Imides**, thus, $(C_4H_4O_2)^{II}HN$ = Succinimide, whilst C_2H_3O,H_2N = Acetamide.

GROUP XIX.—AMIC ACIDS.

In these compounds dyad and triad acid radicals are combined both with Amidogen (NH_2) and Hydroxyl (HO). Thus—

$$(C_4H_4O_2)^{II}HO,H_2N = \text{Succinamic Acid.}$$

GROUP XX.

This group may be said to comprehend all organic substances which cannot be correctly placed in any of the preceding. There is an enormous number of these, and they are derived chiefly from the vegetable and animal kingdoms, viz.: albumen, fibrin and casein.

MONATOMIC ALCOHOL GROUP.

The best known example of this class is ethyl alcohol, or spirits of wine, C_2H_5HO. In common with the rest of the alcohols in the series, this substance may be looked upon as water, $\left.\begin{matrix}H\\H\end{matrix}\right\}O$, in which one atom of H is replaced by a compound radical. Thus—

$$\left.\begin{matrix}H\\H\end{matrix}\right\}O = \text{Water; } \left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O = \text{Ethyl Alcohol.}$$

In the present case the radical is C_2H_5 (ethyl); and the constitution of this alcohol is analogous to caustic potash, $\left.\begin{matrix}K\\H\end{matrix}\right\}O$. A compound of ethyl also exists, viz.: $\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$, which bears exactly the same relation to alcohol (ethylic) as potassium monoxide, $\left.\begin{matrix}K\\K\end{matrix}\right\}O$, does to caustic potash. By the addition of hydrochloric acid, hydrobromic acid, or hydriodic acid to this alcohol, we may obtain ethyl chloride, bromide, or iodide respectively.

The following compounds of ethyl are known, analogous to the salts of potassium.

KNO_3 (Nitrate of Potash);	$C_2H_5NO_3$ (Nitrate of Ethyl).
$KHSO_4$ (Hydric Potassium Sulphate);	$C_2H_5HSO_4$ (Hydric-Ethyl-Sulphate).
K_2SO_4 (Potassium Sulphate);	$(C_2H_5)_2SO_4$ (Ethyl Sulphate).
$KC_2H_3O_2$ (Acetate of Potash);	$C_2H_5C_2H_3O_2$ (Acetate of Ethyl).

By oxidation, ethyl alcohol is first converted into ethyl aldehyde, C_2H_4O, and subsequently into acetic acid, $C_2H_4O_2$, each of which may be considered as an oxidised radical, or as ethyl, in which one atom of oxygen replaces two atoms of hydrogen. Thus ethyl aldehyde is the hydride of a radical (C_2H_3O, or acetyl); C_2H_3OH = hydride of acetyl, or ethyl aldehyde, and acetic acid is the hydroxide of acetyl, C_2H_3OHO.

All primary alcohols are capable of undergoing oxidation, yielding an acid and an aldehyde. All the resulting acids contain only one atom of H, which is replaceable by a metal, and they are therefore *monobasic*. This H may also be replaced by acetyl, giving rise to a substance, $\left.\begin{matrix}C_2H_3O\\C_2H_3O\end{matrix}\right\}O$, called acetate of acetyl, acetic anhydride, or anhydrous acetic acid.

Upon the type ammonia, $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$, a series of compound ammonias are formed by ethyl alcohol. Thus we have—

$$\underset{\text{Ethyl-Amine.}}{\left.\begin{matrix}C_2H_5\\H\\H\end{matrix}\right\}N} \quad ; \quad \underset{\text{Di-Ethyl-Amine.}}{\left.\begin{matrix}C_2H_5\\C_2H_5\\H\end{matrix}\right\}N} \quad ; \quad \underset{\text{Tri-Ethyl-Amine.}}{\left.\begin{matrix}C_2H_5\\C_2H_5\\C_2H_5\end{matrix}\right\}N}$$

Again, a peculiar substance may be formed by the substitution of four atoms of ethyl for four of hydrogen in liquor ammoniæ, $\left.\begin{matrix}N(H_4)\\H\end{matrix}\right\}O$. Thus—

$$\left.\begin{matrix}N(C_2H_5)_4\\H\end{matrix}\right\}O = \text{Tetra-Ethyl-Ammonium Hydrate.}$$

The oxygenised radical of these acids may replace one or more atoms of the hydrogen in ammonia, giving rise to *Amides*. Thus, with acetyl (C_2H_3O), we have—

$$\underset{\text{Acetamide.}}{\left.\begin{matrix}C_2H_3O\\H\\H\end{matrix}\right\}N} \quad ; \quad \underset{\text{Di-acetamide.}}{\left.\begin{matrix}C_2H_3O\\C_2H_3O\\H\end{matrix}\right\}N} \quad ; \quad \underset{\text{Ethyl Di-acetamide.}}{\left.\begin{matrix}C_2H_3O\\C_2H_3O\\C_2H_5\end{matrix}\right\}N}$$

The alcohol radicals also form compounds analogous to the tri-hydrides of phosphorus and arsenic, viz.:

$$P\left\{\begin{matrix}H\\H\\H\end{matrix}\right. = \text{Phosphorus Tri-hydride} ; \left.\begin{matrix}C_2H_5\\C_2H_5\\C_2H_5\end{matrix}\right\}P = \text{Tri-ethyl Phosphine.}$$

$$As\left\{\begin{matrix}H\\H\\H\end{matrix}\right. = \text{Arsenic Tri-hydride} ; \left.\begin{matrix}CH_3\\CH_3\\CH_3\end{matrix}\right\}As = \text{Tri-methyl Arsine.}$$

Lastly, such metals as zinc (Zn) and tin (Stannum, Sn) form compounds with alcohol radicals. Thus we have—

Zinc Ethyl, $Zn \left\{ \begin{matrix} C_2H_5 \\ C_2H_5 \end{matrix} \right.$, corresponding to Zinc Chloride, $Zn \left\{ \begin{matrix} Cl \\ Cl \end{matrix} \right.$; and Stannethyl, $Zn(C_2H_5)_5$, corresponding to Tin Chloride, $SnCl_5$.

SECONDARY ALCOHOLS.

In these the hydroxyl (OH) is attached to a carbon atom, which is situated either between two other carbon atoms or in the centre of the chain. The Monocarbon and Dicarbon Series cannot give rise to any secondary alcohols: the Tricarbon series, containing the radical propyl, being the first in which such compounds are met with.

The formula for secondary propyl alcohol is the following:

$\left\{ \begin{matrix} CH_3 \\ CHOH \\ CH_3 \end{matrix} \right.$ or $C \left\{ \begin{matrix} CH_3 \\ CH_3 \\ H \\ OH \end{matrix} \right.$. It is also called Dimethyl Carbinol.

The formula for Carbinol itself is $C \left\{ \begin{matrix} H \\ H \\ H \\ OH \end{matrix} \right.$, or Methyl Alcohol, CH_3HO; and Methyl Carbinol is $C \left\{ \begin{matrix} CH_3 \\ H \\ H \\ OH \end{matrix} \right.$, or Ethyl Alcohol, C_2H_6O.

When these bodies are oxidised they give up two atoms of H, yielding a *Ketone*, but *no* aldehyde. Thus—

$$\underset{\text{Dimethyl Carbinol.}}{\left\{ \begin{matrix} CH_3 \\ CHOH \\ CH_3 \end{matrix} \right.} - 2H = \underset{\text{Dimethyl Ketone.}}{\left\{ \begin{matrix} CH_3 \\ CO \\ CH_3 \end{matrix} \right.}$$

Ketones form secondary alcohols by taking up H, but do not yield corresponding acids when oxidised.

All secondary alcohols contain the group CH_3, which by oxidation is set free (combined with one carbon atom) as acetic acid, the remaining alcohol radical forming its corresponding acid. The following is the list of

The Secondary Alcohols.

$$C\left\{\begin{matrix}CH_3\\CH_3\\H\\OH\end{matrix}\right., \text{ or } C_3H_8O - \text{Dimethyl Carbinol.}$$

$$C\left\{\begin{matrix}CH_3\\C_2H_5\\H\\OH\end{matrix}\right., \text{ or } C_4H_{10}O - \text{Methyl-Ethyl Carbinol.}$$

$$C\left\{\begin{matrix}CH_3\\C_3H_7\\H\\OH\end{matrix}\right., \text{ or } C_5H_{12}O - \text{Methyl-Propyl Carbinol.}$$

$$C\left\{\begin{matrix}CH_3\\C_4H_9\\H\\OH\end{matrix}\right., \text{ or } C_6H_{14}O = \text{Methyl-Butyl Carbinol.}$$

$$C\left\{\begin{matrix}CH_3\\C_6H_{13}\\H\\OH\end{matrix}\right., \text{ or } C_8H_{18}O - \text{Methyl-Hexyl Carbinol.}$$

TERTIARY ALCOHOLS.

In these the hydroxyl, OH, is attached to an atom of carbon, which is situated between three other carbon atoms. The starting-point of these bodies is the tetra-carbon series, viz.: trimethyl carbinol or tertiary butyl alcohol. The following are

The Tertiary Alcohols.

$$C\left\{\begin{matrix}(CH_3)_3\\OH\end{matrix}\right., \text{ or } C_4H_{10}O = \text{Trimethyl Carbinol.}$$

$$C\left\{\begin{matrix}(CH_3)_2\\C_2H_5\\OH\end{matrix}\right., \text{ or } C_5H_{12}O = \text{Dimethyl-Ethyl Carbinol.}$$

$$C\left\{\begin{matrix}(CH_3)_2\\C_3H_7\\OH\end{matrix}\right., \text{ or } C_6H_{14}O - \text{Dimethyl-Propyl Carbinol.}$$

$$C\left\{\begin{matrix}CH_3\\(C_2H_5)_2\\OH\end{matrix}\right., \text{ or } C_6H_{14}O - \text{Methyl-Diethyl Carbinol.}$$

$$C\left\{\begin{matrix}(C_2H_5)_3\\OH\end{matrix}\right., \text{ or } C_7H_{16}O, - \text{Triethyl Carbinol.}$$

$$C\left\{\begin{matrix}(C_2H_5)_2\\C_3H_7\\OH\end{matrix}\right., \text{ or } C_8H_{18}O, - \text{Diethyl-Propyl Carbinol.}$$

THE MONOCARBON OR METHYL SERIES.

Methyl Alcohol, CH_3HO. This substance is also called *Wood Spirit*, *Hydroxymethane*, or *Carbinol*. It is met with in the oil of winter-green, derived from the *Gaultheria Procumbens*, the oil of which consists of the acid-methyl-salicylate ($CH_3HC_7H_4O_3$); and this alcohol is prepared from that compound by the addition of a solution of potash (KHO). Thus—

$$CH_3HC_7H_4O_3 + KHO = KHC_7H_4O_3 + CH_3HO.$$

Acid-potassium-salicylate and methyl alcohol are formed.

Methyl alcohol is a colourless fluid, having a peculiar odour and an unpleasant taste. It may be obtained pure by decomposing methyl oxalate ($(CH_3)_2C_2O_4$) with water.

The action of sulphuric acid (H_2SO_4) upon methyl alcohol (CH_3HO) is the type of a general action. (Great care must be taken in mixing these substances, as much heat is evolved by their combination.) The following are the reactions:—

$$(a)\ CH_3HO + H_2SO_4 = H_2O + HCH_3SO_4.$$

Water and **Hydrogen-Methyl-Sulphate** are formed.

$$(b)\ HCH_3SO_4 + CH_3HO = \begin{matrix} (CH_3)_2O + H_2SO_4, \\ \text{or} \\ H_2O + (CH_3)_2SO_4. \end{matrix}$$

Another molecule of the alcohol comes in contact with the hydrogen-methyl-sulphate, and one of the above results takes place, *i.e.*, either dimethyl ether, $(CH_3)_2O$, and sulphuric acid are formed, or water and dimethyl sulphate result, according as the excess of the sulphuric acid present is small or great.

Methyl Chloride, CH_3Cl, is a colourless gas, with a sweetish taste and a peculiar odour. It burns with a pale-coloured flame, which is greenish at the edges, and may be prepared from methyl alcohol by the action of sulphuric acid (H_2SO_4) and chloride of sodium ($NaCl$). Thus—

$$(a)\ CH_3HO + H_2SO_4 = H_2O + CH_3HSO_4.$$

Water and hydric-methyl-sulphate are formed, to which chloride of sodium is added. Thus—

$$(b)\ CH_3HSO_4 + NaCl = NaHSO_4 + CH_3Cl.$$

Hydric-sodium-sulphate and methyl chloride are formed, which may be collected over water.

Methyl Hydride.—Marsh Gas, CH_3H. This gas has been to some extent previously described.* By the slow action of chlorine upon this substance several substitution products are formed, the chief amongst them being chloroform.

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* See Part I.

Methyl Ether, or **Methyl Oxide**, $(CH_3)_2O$, is a colourless gas, with an ethereal odour. It is prepared from methyl alcohol and sulphuric acid. Thus—

$$(a)\ CH_3HO + H_2SO_4 = H_2O + CH_3HSO_4.$$
$$(b)\ CH_3HSO_4 + CH_3HO = H_2SO_4 + (CH_3)_2O.$$

Sulphuric acid and methyl ether are formed at the end of the process.

This substance must be collected over mercury.

Methyl Mercaptain, or **Methyl Sulph-Hydrate**, CH_3HS, is a liquid of an offensive odour, prepared by the action of hydrosulphate of potassium (KHS) upon calcium-methyl-sulphate $(Ca(CH_3,SO_4)_2)$. Thus—

$$Ca(CH_3,SO_4)_2 + 2KHS = K_2SO_4 + CaSO_4 + 2CH_3HS.$$

Sulphate of potash, sulphate of lime, and methyl mercaptan are formed.

Methyl Cyanide, CH_3CN, is a colourless liquid with a disagreeable odour, and is prepared by distilling acetate of ammonia $(NH_4C_2H_3O_2)$. Thus—

$$NH_4C_2H_3O_2 - 2H_2O = CH_3CN.$$

The ammonium salt loses two molecules of water, and methyl cyanide results.

Methyl Nitrate, CH_3NO_3, is a colourless, ethereal-smelling liquid, obtained by the action of sulphuric acid (H_2SO_4) and nitrate of potash (KNO_3) upon methyl alcohol. Thus—

$$(a)\ CH_3HO + H_2SO_4 = H_2O + CH_3HSO_4.$$
$$(b)\ CH_3HSO_4 + KNO_3 = KHSO_4 + CH_3NO_3.$$

Hydric-potassium-sulphate and nitrate of methyl are formed.

THE DICARBON, DEUTYL, OR ETHYL SERIES.

Ethyl Alcohol, C_2H_5HO, or **Hydroxyde of Ethyl**, is obtained in the vinous fermentation of sugar, a decomposition effected in aqueous solutions in the presence of yeast, alcohol and carbonic anhydride being chiefly formed; it can also be prepared by synthesis; for if acetylene, C_2H_2, be taken and directly combined with hydrogen (H_2), olefiant gas, C_2H_4, is formed. C_2H_4 combines directly with strong sulphuric acid (H_2SO_4) to form hydrogen-ethyl-sulphate $(C_2H_6SO_4)$, which, when boiled with water (H_2O), forms sulphuric acid and alcohol. Thus—

$$C_2H_6SO_4 + H_2O = H_2SO_4 + C_2H_5HO.$$

Alcohol cannot be entirely separated from water by simple distillation, the strongest spirit thus prepared containing 10 per cent. of water. To withdraw all the water, it is necessary to distil it with potassium carbonate or quicklime, which is capable of uniting with the water. A pure liquid is then formed, to which the name of *Absolute Alcohol* is given. This substance is very inflammable, greedily absorbs moisture, and mixes with water in all proportions, the mixture undergoing contraction and evolving heat: it is also a solvent of organic bases, resins, and essential oils.

The *Proof-Spirit* of the Excise contains 50·8 parts by weight of alcohol to 49·2 of water, and has a specific gravity of ·920 at 15°C.

"Methylated Spirit" is the name given to a substance formed by the addition of 10 parts of wood-spirit to 90 parts of strong alcohol. This is used for scientific and manufacturing purposes.

More or less alcohol is contained in wine, beer and spirits; certain essential oils, sugar, or extracts, being employed as flavouring agents. Whisky, brandy, and other spirits contain from 40 to 50 per cent. of alcohol; wines, from 17 (port and madeira) to 7 or 8 (hock and light clarets) per cent.; porter and strong ale contain from 6 to 8 per cent.

If the vapour of alcohol be passed through a red-hot tube it is decomposed, with the production of hydrogen, marsh-gas, olefiant-gas, benzole, napthaline and other substances.

Alcohol (C_2H_6O), by oxidation, is first converted into ethyl aldehyde (C_2H_4O), and then into acetic acid ($C_2H_4O_2$).

The alkaline metals rapidly attack alcohol with the evolution of hydrogen, and the formation of an alkaline-ethylate. Thus—

$$C_2H_5HO \quad + \quad Na \quad = \quad NaC_2H_5O \quad + \quad H.$$

Alcohol and sodium form sodium-ethylate and hydrogen.

Strong sulphuric acid forms with alcohol, Hydrogen-Ethyl-Sulphate, or Sulphovinic Acid, with which salts termed ethyl-sulphates are formed. Thus we have—Sodium-Ethyl-Sulphate, $Na,C_2H_5SO_4$, and Potassium-Ethyl-Sulphate, $K,C_2H_5SO_4$.

ETHYL HYDRIDE, C_2H_5H, is a tasteless, colourless gas. It may be prepared by heating methyl iodide (CH_3I) in a closed tube with metallic zinc (Zn) to 150°C. Thus—

$$2CH_3I + Zn = ZnI_2 + C_2H_5H.$$

Iodide of zinc and ethyl hydride result.

ETHYL CHLORIDE, C_2H_5Cl is a mobile liquid, with an ethereal

odour. It may be obtained by acting upon alcohol with the pentachloride of phosphorus (PCl_5). Thus—

$$5C_2H_5HO + PCl_5 = H_3PO_4 + H_2O + 5C_2H_5Cl.$$

Tribasic phosphoric acid and water are formed, the chloride of ethyl volatilising and being condensed in a freezing mixture.

Ethyl Bromide (C_2H_5Br) and **Ethyl Iodide** (C_2H_5I) may be obtained by the action of bromine or iodine upon alcohol in the presence of phosphorus.

Ether, Ethyl Oxide, $(C_2H_5)_2O$, is a fragrant colourless liquid, burning with a white flame, boiling at 35°C, and having a specific gravity of 0·720. It yields the same products as alcohol when exposed to oxidising agents, and is acted upon by chlorine, giving rise to numerous substitution products. It may be prepared by the following methods :—

(1) By acting upon ethylate of potassium (KC_2H_5O) with iodide of ethyl (C_2H_5I). Thus—

$$KC_2H_5O + C_2H_5I = KI + (C_2H_5)_2O.$$

Iodide of potassium and ethylic-ether are formed.

(2) By the addition of sulphuric acid (H_2SO_4) to ethylic alcohol (C_2H_6O). Thus—

$$(a)\ C_2H_6O + H_2SO_4 = H_2O + C_2H_6SO_4.$$

Water and sulphovinic acid are formed. A second molecule of alcohol encounters the sulphovinic acid. Thus—

$$(b)\ C_2H_6SO_4 + C_2H_6O = H_2SO_4 + (C_2H_5)_2O.$$

Sulphuric acid and ether are formed.

The above is termed the *Continuous Etherification Process*, since through the sulphuric acid, heated to 140°C, a stream of alcohol may be continuously passed, a regular supply of water and ether being obtained.

Mixed Ethers (ethers in which two radicals are contained) are formed by acting, for example, with methylate of potassium (KCH_3O) upon iodide of ethyl (C_2H_5I). Thus—

$$KCH_3O + C_2H_5I = KI + CH_3,C_2H_5O.$$

Iodide of potassium and methyl-ethyl-ether are formed.

The following is a list of some of the simple and mixed ethers of this series:

* TABLE OF SIMPLE AND MIXED ETHERS.

Dimethyl Ether	C_2H_6O	$\left.\begin{matrix}CH_3\\CH_3\end{matrix}\right\}O$
Methyl-Ethyl-Ether	C_3H_8O	$\left.\begin{matrix}CH_3\\C_2H_5\end{matrix}\right\}O$
Diethyl Ether	$C_4H_{10}O$	$\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$
Methyl-Amyl-Ether	$C_6H_{14}O$	$\left.\begin{matrix}CH_3\\C_5H_{11}\end{matrix}\right\}O$
Ethyl-Butyl-Ether	$C_6H_{14}O$	$\left.\begin{matrix}C_2H_5\\C_4H_9\end{matrix}\right\}O$
Ethyl-Amyl-Ether	$C_7H_{16}O$	$\left.\begin{matrix}C_2H_5\\C_5H_{11}\end{matrix}\right\}O$
Dibutyl Ether	$C_8H_{18}O$	$\left.\begin{matrix}C_4H_9\\C_4H_9\end{matrix}\right\}O$
Ethyl-Hexyl-Ether	$C_8H_{18}O$	$\left.\begin{matrix}C_2H_5\\C_6H_{13}\end{matrix}\right\}O$
Diamyl Ether	$C_{10}H_{22}O$	$\left.\begin{matrix}C_5H_{11}\\C_5H_{11}\end{matrix}\right\}O$

ETHYL CYANIDE, C_2H_5CN, is formed along with its isomer, PROPIONITRIL, by the action of silver cyanide ($AgCN$) upon iodide of ethyl (C_2H_5I). Thus—

$$C_2H_5I + AgCN = AgI + C_2H_5CN.$$

Iodide of silver is formed at the same time.

PROPIONITRIL may also be obtained by distilling potassium cyanide (KCN) with potassium-ethyl-sulphate (K,C_2H_5,SO_4). Thus—

$$KCN + K,C_2H_5,SO_4 = K_2SO_4 + C_2H_5CN.$$

Sulphate of potash being also formed.

When this substance is heated with potash it yields *Propianic Acid* ($C_3H_6O_2$) ; and it may thus be regarded as a nitrogen compound (*nitril*) of the next higher carbon series (propyl). Thus—

$$C_3H_5N + 2H_2O = C_3H_6O_2 + NH_3.$$

Propionitril and water yield propianic acid and ammonia.

By acting upon propionitril with hydrogen (H) we obtain propylamine. Thus—

$$C_2H_5CN + 4H = \left.\begin{matrix}C_3H_7\\H_2\end{matrix}\right\}N = \text{Propylamine.}$$

The above reaction is common to all the series of alcoholic cyanides, and by it we can pass from a lower to a higher carbon series. In the present instance, from the 2nd carbon to the 3rd carbon series.

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* Roscoe.

Ethyl Nitrite, $C_2H_5NO_2$, is a pale-yellow, volatile liquid, having an apple-like odour. It is prepared by acting upon alcohol with nitric acid. It is contained in the spiritus etheris nitrosi of the British Pharmacopœia.

Ethyl Nitrate, $C_2H_5NO_3$, is only formed by the action of nitric acid upon alcohol in the presence of urea, since this substance destroys any nitrous acid that may be formed, and which would obviate the production of the nitrate. It possesses a sweet taste and odour, and is not miscible with water.

Ethyl Sulph-Hydrate or Mercaptan, C_2H_5HS, is a limpid, colourless liquid, smelling strongly of onions; it is very inflammable, and burns with a blue flame.

It is obtained by the action of potassium-sulph-hydrate (KHS) upon calcium-ethyl-sulphate ($Ca(C_2H_5)_2(SO_4)_2$). Thus—

$$Ca(C_2H_5)_2(SO_4)_2 + 2KHS = CaSO_4 + K_2SO_4 + 2C_2H_5HS.$$

Sulphate of lime, sulphate of potash, and ethyl sulphhydrate are formed.

This substance can replace its typical hydrogen by metals, and forms an insoluble compound with mercury.

Ethyl Sulphide, $(C_2H_5)_2S$, is a colourless liquid, with a disagreeable odour; it may be obtained by acting upon sulphide of potassium (K_2S) with ethyl chloride, $(C_2H_5)Cl$. Thus—

$$K_2S + 2C_2H_5Cl = 2KCl + (C_2H_5)_2S.$$

Chloride of potassium and ethyl sulphide are formed.

Sulpho-Ethylic Acid, Sulphovinic Acid, or Hydric-Ethyl-Sulphate, $C_2H_5HSO_4$, is a colourless liquid formed by acting upon alcohol (C_2H_5HO) with strong sulphuric acid (H_2SO_4). Thus—

$$C_2H_5HO + H_2SO_4 = H_2O + C_2H_5HSO_4.$$

Water and sulpho-ethylic acid are formed.

This acid form salts in which the typical hydrogen is replaceable by a metal.

Di-Ethyl Sulphate, $(C_2H_5)_2SO_4$, is prepared by the action of sulphuric anhydride (SO_3) upon ethylic-ether, $(C_2H_5)_2O$. Thus—

$$(C_2H_5)_2O + SO_3 = (C_2H_5)_2SO_4.$$

The **Ethyl Phosphates** correspond to the tribasic alkaline phosphates and contain 1, 2, or 3 molecules of ethyl, by which the hydrogen in tribasic phosphoric acid is replaced: they are the following, viz.:

$H_2C_2H_5PO_4$;	$H(C_2H_5)_2PO_4$;	$(C_2H_5)_3PO_4$;
Dihydric Ethyl Phosphate;	Hydric Diethyl Phosphate;	Triethyl Phosphate.

Ethyl Cyanate, C_2H_5CNO, is a colourless liquid, with a strong irritating odour. It may be prepared by the distillation of potassium cyanate (KCNO) with potassium-ethyl-sulphate ($KC_2H_5SO_4$). Thus—

$$KCNO + KC_2H_5SO_4 = K_2SO_4 + C_2H_5CNO.$$

Sulphate of potash and ethyl cyanate are formed.

When this substance is added to caustic potash (KHO), ethylamine (C_2H_5,H_2N) and carbonate of potash (K_2CO_3) are formed. Thus—

$$C_2H_5CNO + 2KHO = C_2H_5,H_2N + K_2CO_3.$$

Ethyl Carbonate, $(C_2H_5)_2CO_3$, corresponds to potassium carbonate (H_2CO_3) and may be obtained by the action of iodide of ethyl (C_2H_5I) upon carbonate of silver (Ag_2CO_3). Thus—

$$Ag_2CO_3 + 2C_2H_5I = 2AgI + (C_2H_5)_2CO_3.$$

Iodide of silver and ethyl carbonate result.

Ethyl Borate $(C_2H_5)_3BO_3$ and various **Ethyl Silicates** are also known.

The so-called **Ethyl Radical** must be regarded as *Butyl Hydride*, C_4H_9H, or $2(C_2H_5)$.

No ethyl compounds can be prepared from C_4H_9H; but when this substance is treated with chlorine, the chloride of the tetracarbon radical, *i.e.*, C_4H_9Cl, or *Butyl Chloride*, is produced.

THE TRICARBON OR PROPYL SERIES.

Primary Propyl Alcohol, C_3H_7HO. This is a colourless liquid obtained in the last products of the distillation of French brandies. It may be prepared by the action of hydrogen (H) upon acetone ($(CH_3)_2CO$). Thus—

$$(CH_3)_2CO + 2H = C_3H_7HO.$$

Sulphuric acid unites with propyl alcohol to form **Hydric-Propyl-Sulphate,** $C_3H_7HSO_4$. By the oxidation of this alcohol **Propianic Acid** is formed.

Secondary Propyl Alcohol, or Dimethyl Carbinol, $C(CH_3)_2H,HO$, may be prepared from isopropyl iodide. By acting upon this last-named substance first with hydrogen, then with chlorine, thirdly with sodium-acetate, and lastly with caustic potash, we may obtain *primary* propyl alcohol. Thus from a secondary alcohol a primary alcohol can be procured.

THE TETRACARBON OR BUTYL SERIES.

Butyl Alcohol, C_4H_9HO, is one of the last products of the distillation of spirits from the molasses of beetroot.

It is also present in coal oils, and in the light oils from American petroleum. This alcohol, on oxidation, yields butyric acid and butyl aldehyde; it is therefore the *Primary* alcohol.

Three other isomeric modifications exist, viz. :

(1) C,C_2H_5,CH_3,H,OH; Secondary Butyl Alcohol, or Ethyl-Methyl Carbinol.

(2) $C,CH,(CH_3)_2,H_2OH$; Fermentation Butyl Alcohol.

(3) C,CH_3,CH_3,CH_3,OH; Tertiary Butyl Alcohol, or Tri-Methyl Carbinol.

The nitrate, chloride, iodide, and the ether of the butyl series are known.

THE PENTA-CARBON OR AMYL SERIES.

AMYL ALCOHOL, $C_5H_{11}HO$, sometimes called fousel oil, oil of grain, or oil of potato spirit, is formed during the distillation of potatoes, corn, etc. It appears at the end of the process, and is then purified by washing and rectification. It is a colourless oily liquid, with a peculiar odour, a hot and acrid taste. With sulphuric acid and this substance, **HYDRIC-AMYL-SULPHATE**, $C_5H_{11}HSO_4$, is formed.

This alcohol furnishes an illustration of *physical isomerism*, since we are acquainted with two modifications of it; one by which the plane of polarization is deviated to the right, the other by which it is unaffected, and which boils at a point two degrees lower than the first; yet in their chemical characters and constitution the two are exactly identical.

In the presence of oxygen (O), or platinum black, amyl alcohol is oxidised to **VALERIANIC ACID** ($C_5H_{10}O_2$). Thus—

$$C_5H_{11}HO + 2O = H_2O + C_5H_{10}O_2.$$

Amylates of sodium and potassium may be formed by replacing the hydrogen of this alcohol by sodium or potassium.

AMYL ETHER, $(C_5H_{11})_2O$, is prepared as a colourless liquid by acting upon amyl iodide ($C_5H_{11}I$) with potassium amylate ($KC_5H_{11}O$). Thus—

$$C_5H_{11}I + KC_5H_{11}O = KI + (C_5H_{11})_2O.$$

Iodide of potassium and amyl ether are formed.

AMYL HYDRIDE, $C_5H_{11}H$, occurs in the light oils obtained by the distillation of coal; it also exists in American petroleum.

AMYL ACETATE, $C_5H_{11},C_2H_3O_2$, may be obtained by the distillation of amyl alcohol ($C_5H_{11}HO$) with sulphuric acid (H_2SO_4) and acetate of potash ($KC_2H_3O_2$). Thus—

$$C_5H_{11}HO + H_2SO_4 + KC_2H_3O_2 = KHSO_4 + H_2O + C_5H_{11}C_2H_3O_2.$$

Potassium-hydric-sulphate, water, and amyl acetate are formed.

This substance possesses the odour of Jargonelle pears, and is used for making the sweetmeats known as "peardrops."

THE HIGHER ALCOHOLS.

Hexyl Alcohol, $C_6H_{13}HO$, is obtained from American petroleum.

Heptyl Alcohol, $C_7H_{15}HO$, is an oily, colourless, aromatic fluid, insoluble in water; it is obtained by the action of hydrogen (H) upon œnanthylic aldehyde ($C_7H_{14}O$). Thus—

$$C_7H_{14}O + 2H = C_7H_{15}HO.$$

Octyl Alcohol, $C_8H_{17}HO$, is an aromatic limpid fluid, obtained by the distillation of potash with castor oil.

Cetyl Alcohol, $C_{16}H_{33}HO$, is a white crystalline solid, prepared from potash (KHO) and spermaceti (palmitate of cetyl, $C_{16}H_{33},C_{16}H_{31}O_2$). Thus—

$$C_{16}H_{33},C_{16}H_{31}O_2 + KHO = KC_{16}H_{31}O_2 + C_{16}H_{33}HO.$$

Palmitate of potash and cetyl alcohol are formed.

Ceryl, or Cerotyl Alcohol, $C_{27}H_{55}HO$, is a white solid, formed by the action of potash (KHO) upon Chinese wax or cerotate of ceryl ($C_{27}H_{53},C_{27}H_{53}O_2$). Thus—

$$C_{27}H_{55},C_{27}H_{53}O_2 + KHO = KC_{27}H_{53}O_2 + C_{27}H_{55}HO.$$

Cerotate of potash and cerotyl alcohol are formed.

Melisyl Alcohol, $C_{30}H_{61}HO$, is a crystalline substance, having a silky lustre. It is contained in beeswax; this wax contains myricin, or palmitate of melisyl. When melisyl alcohol is fused with potash, **Melissic Acid**, $C_{30}H_{60}O_2$ is produced.

In addition to the monatomic or primary alcohols already described, the following exist:—

Vinyl Alcohol,	C_2H_3HO.	**Styryl Alcohol**,	C_9H_9HO.
Allyl Alcohol,	C_3H_5HO.	**Cholesterine**,	$C_{26}H_{43}HO$.
Camphol,	$C_{10}H_{17}HO$.		

THE COMPOUNDS OF THE ALCOHOL RADICALS WITH NITROGEN.

Compound Alcoholic Ammonias.

Primary Monamines, as **Ethylamine**, $\left.\begin{matrix}C_2H_5\\H_2\end{matrix}\right\}N.$

Secondary Monamines, as **Di-Ethylamine**, $\left.\begin{matrix}C_2H_5\\C_2H_5\\H\end{matrix}\right\}N.$

Tertiary Monamines, as **Tri-Ethylamine**, $\left.\begin{matrix}C_2H_5\\C_2H_5\\C_2H_5\end{matrix}\right\}N.$

These are all volatile; they possess an ammoniacal odour, and a strong alkaline reaction, and form salts with hydrochloric acid.

The compound ammonias may be formed by the following methods :—

(1) By acting upon the cyanates of the alcohol radicals with caustic alkalies. Thus—

$$C_2H_5CNO + 2KHO = K_2CO_3 + C_2H_5H_2N.$$

Ethyl cyanate and caustic potash yield carbonate of potash and ethylamine.

(2) By acting upon ammonia with the iodides of the alcohol radicals, by which means the iodide of the compound ammonium is formed; this, when treated with potash, forms the compound ammonia. Thus—

$$C_2H_5I + NH_3 = HI + C_2H_5,H_2N.$$

Ethyl iodide and ammonia yield hydriodic acid and ethylamine.

Ethyl iodide acts upon ethylamine, with the production of hydriodic acid and di-ethylamine. Thus—

$$C_2H_5I + C_2H_5H_2N = HI + (C_2H_5)_2HN.$$

It acts similarly upon di-ethylamine, forming tri-methylamine. Thus—

$$C_2H_5I + (C_2H_5)_2HN = HI + (C_2H_5)_3N.$$

A substance termed Tetra-Ethylammonium-Iodide, $(C_2H_5)_4NI$, is formed by the combination of ethyl iodide with tri-ethylamine.

With tetrachloride of platinum the compound ammonias form double salts, and the platinum salt is the more soluble, as the number of organic radicals contained is larger.

PRIMARY MONAMINES.

Methylamine ...	$(CH_3)H_2N.$	Amylamine ...	$(C_5H_{11})H_2N.$
Ethylamine ...	$(C_2H_5)H_2N.$	Heptylamine ...	$(C_7H_{15})H_2N.$
Propylamine ...	$(C_3H_7)H_2N.$	Caproylamine ...	$(C_6H_{13})H_2N.$
Butylamine ...	$(C_4H_9)H_2N.$	Octylamine ...	$(C_8H_{17})H_2N.$

SECONDARY MONAMINES.

Di-Methylamine	$(CH_3)_2HN.$
Di-Ethylamine	$(C_2H_5)_2HN.$
Methyl-Ethylamine	$(CH_3,C_2H_5)HN.$
Di-Amylamine	$(C_5H_{11})_2HN.$

TERTIARY MONAMINES.

Tri-Methylamine	$(CH_3)_3N$.
Tri-Ethylamine	$(C_2H_5)_3N$.
Di-Ethyl-Amylamine	$(C_2H_5)_2,C_5H_{11}N$.
Tri-Amylamine	$(C_5H_{11})N$.
Methyl-Ethyl-Amylamine ...	$CH_3,C_2H_5,C_5H_{11}N$.

From the above table it will be observed that it is possible to have two or more bases of the same composition, but of different constitution; C_3H_9N stands equally for Tri-Methylamine and Methyl-Ethylamine.

COMPOUNDS OF THE ALCOHOL RADICALS WITH PHOSPHORUS.

These bodies correspond to the preceding, but contain phosphorus in place of nitrogen; thus, by acting upon zinc ethyl with trichloride of phosphorus, we may obtain Tri-Methyl-Phosphine, $(C_2H_5)_3P$.

This last substance is a colourless liquid, possessing a disagreeable and powerful odour. Unlike the foregoing nitrogen bases, it combines directly with oxygen, chlorine and sulphur; with ethyl iodide it forms a substance termed Iodide of Tetra-Ethyl Phosphonium, $(C_2H_5)_4PI$.

MONETHYL PHOSPHINE, C_2H_5,H_2P, and DIETHYL PHOSPHINE, $(C_2H_5)_2P$, may be obtained by the action of ethyl iodide upon phosphonium iodide (PH_4I) in the presence of zinc oxide.

COMPOUNDS OF THE ALCOHOL RADICALS WITH ARSENIC.

The following substances are known in the Methyl Series, viz.:—

(1) Tri-Methyl-Arsine	$(CH_3)_3As$.
(2) Arsen-Di-Methyl	$(CH_3)_2As$.
(3) Arsen-Mono-Methyl	$(CH_3)As$.

TRI-METHYL-ARSINE is constructed upon the type ammonia; the other two unite directly with one or two atoms of chlorine respectively, and then form compounds upon the general type, $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$. The following are known:

Arseniuretted Hydrogen	AsH,H,H.
Tri-Methyl-Arsine	$AsCH_3,CH_3,CH_3$.

Arsen-Di-Methyl Chloride ...	$AsCH_3,CH_3,Cl$.
Arsen-Monomethyl Di-Chloride ...	$AsCH_3,Cl,Cl$.
Arsenic Tri-Chloride	$AsCl,Cl,Cl$.

Tri-Methyl-Arsine is a colourless liquid, formed by acting upon an alloy of sodium and arsenic with methyl iodide.

Arsen-Di-Methyl, or Cacodyl, $As(CH_3)_2$, may be prepared by heating acetate of potash with arsenious anhydride. It is a colourless liquid, of a garlic odour, and extremely poisonous, taking fire in contact with air. One of its important compounds is *Cacodylic Acid* ($As(CH_3)_2HO_2$). This is soluble in water, and not poisonous.

COMPOUNDS OF THE ALCOHOL RADICALS WITH ANTIMONY, BISMUTH, AND BORON.

Tri-Ethyl-Stibine, $(C_2H_5)_3Sb$, is obtained by acting with an alloy of potassium and antimony upon ethyl iodide. This substance forms a compound with oxygen, chlorine, and sulphur; is a colourless liquid, and takes fire in contact with air.

Tri-Eth-Bismutine, $(C_2H_5)_3Bi$, is a compound analogous to the foregoing antimony compound.

A corresponding compound with Boron is known, Bor-Ethyl ($(C_2H_5)_3B$), which takes fire in air, burning with a green flame.

COMPOUNDS OF THE ALCOHOL RADICALS WITH METALS.

Zinc Ethyl, $(C_2H_5)_2Zn$, may be obtained by the action of metallic zinc upon ethyl iodide. It is a colourless liquid, burning in air or oxygen with a greenish flame, and forming ethylate of zinc ($Zn(C_2H_5)_2O$), when the oxidation proceeds slowly.

When zinc ethyl acts upon silicon tetrachloride, Silicon Ethyl is obtained; when upon mercuric chloride, Mercuric Ethyl is formed; and on lead chloride, Lead Ethyl is formed.

Compounds of the alcohol radicals with tin, lead, and some other metals, can be prepared, the properties of which are somewhat analogous to the preceding.

Compounds of ethyl with the *Alkaline Metals* have also been obtained.

Sodium Ethyl (NaC_2H_5) will combine directly with carbonic anhydride (CO_2), forming Sodium Propionate. Thus—

$$Na,C_2H_5 + CO_2 = NaC_3H_5O_2.$$

COMPOUNDS RESULTING FROM THE OXIDATION OF THE ALCOHOLS.

It will have been observed that such oxidised products as the aldehydes and acids contain a radical, in which two atoms of hydrogen (H_2) in the alcoholic radical are replaced by one of oxygen (O). Thus—

Methyl Alcohol, $\left.\begin{matrix}CH_3\\H\end{matrix}\right\}O$, yields Formic Acid, $\left.\begin{matrix}CHO\\H\end{matrix}\right\}O$.

Ethyl Alcohol, $\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O$, yields Acetic Acid, $\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O$.

By the substitution of an atom of chlorine (Cl) for the hydroxyl (HO) of an acid, the chloride is obtained. Thus—

Acetic Acid, $\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O$, yields C_2H_3OCl, Acetyl Chloride.

The hydrogen of the hydroxyl (HO) may also be replaced by alcohol radicals or metals; and thus we have—

Hydric Acetate, $\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O$; Ethyl Acetate, $\left.\begin{matrix}C_2H_3O\\C_2H_5\end{matrix}\right\}O$;

Potassium Acetate, $\left.\begin{matrix}C_2H_3O\\K\end{matrix}\right\}O$.

A fatty acid may be reduced to an aldehyde by the distillation of a salt of such acid with a formiate. Thus—

$$\underset{KC_2H_3O_2}{\text{Potassium Acetate.}} + \underset{KCHO_2}{\text{Potassium Formiate.}} = \underset{K_2CO_3}{\text{Potassium Carbonate.}} + \underset{C_2H_4O.}{\text{Ethyl Aldehyde.}}$$

By replacement of the oxygen in the hydroxyl by sulphur we obtain—

$\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}S$;	$\left.\begin{matrix}C_2H_3O\\K\end{matrix}\right\}S$;	$\left.\begin{matrix}C_2H_3O\\C_2H_5\end{matrix}\right\}S$.
Thiacetic Acid.	Thiacetate of Potash.	Thiacetate of Ethyl.

Upon the ammonia type, $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$, are formed the Amides. Thus—

$$\left.\begin{matrix}C_2H_3O\\H\\H\end{matrix}\right\}N\text{, Acetamide.}$$

If we write Acetic Acid thus, $\left.\begin{matrix}CH_3CO\\H\end{matrix}\right\}O$, we shall see that this acid is a compound of an alcohol radical (CH_3, Methyl) with the monad group, $\left.\begin{matrix}CO\\H\end{matrix}\right\}O$, to which the name of CARBOXYL is given. It must be considered as entering into the composition of all the fatty acids, and it is obvious that it is formed by the oxidation of methyl (CH_3), since—

$$\left\{\begin{matrix}CH_3\\CH_3\end{matrix}\right. = \text{Ethyl Hydride}; \quad \left\{\begin{matrix}CH_3\\CH_2OH\end{matrix}\right. = \text{Ethyl Alcohol};$$

$$\left\{\begin{matrix}CH_3\\COOH\end{matrix}\right. = \text{Acetic Acid.}$$

The MONOBASIC ACIDS may be obtained in the following modes:

(1) By the direct oxidation of the alcohol having the same number of carbon atoms. Thus—

$$C_2H_5HO + O = H_2O + C_2H_4O_2.$$

Ethyl Alcohol and Oxygen = Water and Acetic Acid.

(2) From the alcohol possessing one atom less of carbon. Thus—

(*a*) By decomposing the alcoholic cyanide with potash, as follows:—

$$C_2H_5CN \text{ yields } C_3H_6O_2.$$

Ethyl Cyanide. Propianic Acid.

(*b*) By the action of carbonic anhydride upon the sodium compound. Thus—

$$Na(C_2H_5) + CO_2 = NaC_3H_5O_2.$$

Sodium ethyl and carbonic anhydride yield propionate of sodium.

THE MONOCARBON SERIES.

FORMIC ACID (CH_2O_2). This acid is found in stinging-nettles, and exists (ready formed), in the bodies of ants and caterpillars; it is also said to enter into the composition of the poison of the bee and wasp.

Preparation.—(1) By the oxidation of methy-alcohol. Thus—

$$CH_3HO + 2O = H_2O + CH_2O_2.$$

Methyl-alcohol and oxygen yield water and formic acid.

(2) By the decomposition of oxalic acid ($C_2H_2O_4$), in the presence of glycerine and water, in which process carbonic anhydride and formic acid are formed.

(3) By synthesis, *i.e.*, the addition of carbonic oxide (CO), at 100°C., to liquor potassæ (KHO). Thus—

$$CO + KHO = KCHO_2 \text{ (Formiate of Potash).}$$

Formic acid is a colourless liquid having a strong acid taste and a sharp peculiar odour. It forms salts called formiates, which are all soluble in water. It reduces the salts of mercury, silver, gold, and platinum to the metallic state. Formiates, when heated with excess of baryta yield oxalates.

Formamide, $\left.\begin{matrix}CH\\H\\H\end{matrix}\right\}N$, is a colourless liquid prepared by the action of ammonia upon formiate of ethyl.

THE DICARBON SERIES. ACETYL COMPOUNDS.

Acetyl Hydride, or Ethylic Aldehyde, $\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}$, may be obtained by the oxidation of dilute alcohol with sulphuric acid and black oxide of manganese, or by the action of formiate of potassium ($KCHO_2$) upon acetate of potassium ($KC_2H_3O_2$). Thus—

$$KC_2H_3O_2 + KCHO_2 = K_2CO_3 + C_2H_4O.$$

Carbonate of potash and ethyl aldehyde are formed.

This aldehyde reduces silver from its compounds, and unites directly with nascent hydrogen to form ethyl alcohol. Thus—

$$C_2H_4O + H_2 = C_2H_6O.$$

Aldehyde may exist in three polymeric modifications, viz.: Metaldehyde (C_2H_4O). Acraldehyde $2(C_2H_4O)$. Paraldehyde $3(C_2H_4O)$.

This aldehyde is also isomeric with oxide of ethylene, and forms with ammonia a substance called Aldehyde Ammonia, $\left.\begin{matrix}C_2H_3O\\NH_4\end{matrix}\right\}$. In its reactions aldehyde often acts as the oxide of a dyad radical (C_2H_4), which is termed Ethylidene.

Acetal, $\left.\begin{matrix}C_2H_4\\(C_2H_5)_2\end{matrix}\right\}O_2$, is a derivative of aldehyde, and may be obtained by heating alcohol with aldehyde.

Di-Methyl Acetal, $\left.\begin{matrix}C_2H_4\\(CH_3)_2\end{matrix}\right\}O_2$, a substance similar in composition to acetal, is found in crude wood-spirit.

Chloral, $\left.\begin{matrix}C_2Cl_3O\\H\end{matrix}\right\}$, may be regarded as aldehyde in which three atoms of hydrogen are replaced by three of chlorine.

This substance reduces the silver salts and forms a crystalline compound with ammonia, $\left.\begin{matrix}C_2Cl_3O\\NH_4\end{matrix}\right\}$, or chloral ammonia.

It may be obtained by passing chlorine (Cl) through absolute alcohol (C_2H_6O). Thus—

$$C_2H_6O + 8Cl = 5HCl + C_2Cl_3HO.$$

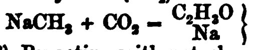
Hydrochloric acid and chloral are formed.

Acetic Acid, Hydric Acetate, $\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O$, exists, although in small quantity, in the juices of some vegetables and plants. It may be prepared by the following processes :—

(1) By the oxidation of alcohol. Thus—

$$C_2H_5HO + 2O = H_2O + C_2H_4O_2.$$

(2) By direct union of sodium methyl ($NaCH_3$) with carbonic anhydride (CO_2).



$$NaCH_3 + CO_2 = \left.\begin{matrix} C_2H_3O \\ Na \end{matrix}\right\} O,$$ or Acetate of Sodium.

(3) By acting with potash upon cyanide of methyl.

(4) By the dry distillation of wood; the acid thus obtained being termed *Pyroligneous Acid.*

THE ACETOUS FERMENTATION.

This term is applied to the process by which such alcoholic fluids as wine and beer are oxidised to acetic acid. These fluids are exposed to the action of the air for about fourteen days at a temperature of about 25°C., the alcohol then becomes converted into *Acetum*, or vinegar. The change is apparently caused by the presence of the *mycoderma aceti* (a peculiar vegetable growth), which, floating upon the surface of the liquid, yields alcohol after the absorption of oxygen.

Pure Acetic Acid is prepared by heating the acetate of sodium ($NaC_2H_3O_2$) with strong sulphuric acid (H_2SO_4). Thus—

$$2NaC_2H_3O_2 + H_2SO_4 = Na_2SO_4 + 2HC_2H_3O_2.$$

Sulphate of sodium and acetic acid are formed.

Thus prepared, acetic acid is a colourless liquid, setting to an ice-like solid at 17°C, (hence the name "*Glacial*" acetic acid), and having a boiling-point of 118°C.

It possesses a strong acid taste, and a sharp peculiar smell. With perchloride of iron this acid yields a *cherry-red* colour.

ACETYL CHLORIDE, C_2H_3OCl; ACETYL BROMIDE, C_2H_3OBr; and ACETYL IODIDE, C_2H_3OI, are known.

ACETATE OF ACETYL, or ACETIC ANHYDRIDE, $C_4H_6O_3$, or $C_2H_3O,C_2H_3O_2$, is a colourless fluid, which is obtained by the action of acetyl chloride (C_2H_3OCl) upon acetate of sodium ($NaC_2H_3O_2$). Thus—

$$NaC_2H_3O_2 + C_2H_3OCl = NaCl + (C_2H_3O)_2O.$$

Chloride of sodium and acetate of acetyl are formed.

ACETYL PEROXIDE, $(C_2H_3O)_2O_2$, may be obtained by acting upon dioxide of barium (BaO_2) with acetate of acetyl ($C_2H_3O,C_2H_3O_2$). Thus—

$$2C_2H_3O,C_2H_3O_2 + BaO_2 = Ba2C_2H_3O_2 + (C_2H_3O)_2O_2.$$

Acetate of barium and acetyl peroxide result.

Chloracetic Acids. Chlorine may act upon acetic acid, replacing one, two, or three atoms of the hydrogen of the radical acetyl. Thus—

$$\left.\begin{array}{c} C_2H_2ClO \\ H \end{array}\right\} O = \text{Monochloracetic Acid;}$$

$$\left.\begin{array}{c} C_2HCl_2O \\ H \end{array}\right\} O = \text{Dichloracetic Acid;}$$

$$\left.\begin{array}{c} C_2Cl_3O \\ H \end{array}\right\} O = \text{Trichloracetic Acid.}$$

These acids form salts analogous to the acetates, and by the action of nascent hydrogen acetic acid may be generated from them.

Thiacetic Acid, C_2H_3OHS, is a substance which bears the same relation to acetic acid as mercaptan does to alcohol. It is a colourless liquid with a nauseous smell; and may be obtained by acting upon acetic acid ($HC_2H_3O_2$) with pentasulphide of phosphorus (P_2S_5). Thus—

$$5HC_2H_3O_2 + P_2S_5 = P_2O_5 + 5C_2H_3O,HS.$$

Pentoxide of phosphorus and thiacetic acid are formed.

Thiacetic Anhydride, $(C_2H_3O)_2S$, also exists.

Acetamide, or Acetyl Ammonia, $\left.\begin{array}{c} C_2H_3O \\ H \\ H \end{array}\right\} N$, is a colourless solid, and may be obtained by the action of acetate of ethyl upon ammonia. Thus—

$$C_2H_5,C_2H_3O_2 + NH_3 = C_2H_5HO + C_2H_3OH_2N.$$

Alcohol and acetamide are formed.

Diacetamide, $(C_2H_3O)_2HN$, is known; as is also **Ethyl Diacetamide**, $C_2H_5(C_2H_3O)_2N$.

Acetone, $CH_3C_2H_3O$, may be considered as methyl acetyl. It is a colourless liquid, and may be formed by the action of zinc methyl ($(CH_3)_2Zn$) upon acetyl chloride (C_2H_3OCl). Thus—

$$(CH_3)_2Zn + 2C_2H_3O,Cl = ZnCl_2 + 2CH_3C_2H_3O.$$

Chloride of zinc and acetone being formed.

HIGHER FATTY ACIDS.

These substances, with their formulæ, will be found in the table on page 25. They occur in many natural fats, and are all obtained by acting upon beef or mutton stearine with nitric acid. They resemble, in their general characteristics, the first two of the series, viz. formic and acetic acids.

These acids may be prepared *synthetically* in the following modes:

(1) By the direct combination of carbonic anhydride with the sodium or potassium compound of the next lower alcohol radical.

(2) By acting with potash upon the cyanide of the next lower alcohol radical.

(3) By the replacement of one or two atoms of hydrogen in the radicals of the fatty acids by alcohol radicals.

Most of these acids are oily fluids forming well-defined salts. The higher members of the series occur in all fatty bodies.

Stearic and palmitic acids are solid substances, and are obtained by the decomposition of the soaps made from beef-suet and palm-oil, which consist of stearate and palmitate of potassium.

By these acids are formed Anhydrides, Chlorides, Aldehydes, Amides, Acetones, and Compound Ethers, which correspond with the same compounds in the Acetyl Series in their general chemical characters and constitution.

Some of the most simple terms of the group of monatomic acids and alcohols may be prepared synthetically from their elements, and from these lower terms by the addition of carbon and hydrogen, we may pass to the higher ones, and thus ascend the series.

From inorganic sources marsh gas (CH_4) may be prepared as follows:

$$(1)\ 2H_2S + 8Cu + CS_2 = 4Cu_2S + CH_4.$$

Sulphuretted hydrogen, metallic copper, and disulphide of carbon yield sulphide of copper and marsh gas:

$$(2)\ CH_4 + 2Cl = HCl + CH_3Cl.$$

Marsh gas and chlorine gas give hydrochloric acid and methyl chloride:

$$(3)\ CH_3Cl + KHO = KCl + CH_3HO.$$

Methyl chloride and liquor potassæ yield chloride of potassium and methyl alcohol.

We now pass to the dicarbon series by the following methods:

$$(a)\ CH_3HO + AgCN = AgHO + CH_3CN.$$

Methyl alcohol and silver cyanide yield silver hydrate and acetonitril.

$$(b)\ CH_3CN + H_2O + KHO = NH_3 + KC_2H_3O_2.$$

Acetonitril, water, and liquor potassæ give ammonia and acetate of potash.

(*c*) $KC_2H_3O_2 + KCHO_2 = K_2CO_3 + C_2H_4O$.

Acetate of potash and formiate of potash give carbonate of potash and ethyl aldehyde.

(*d*) $C_2H_4O + 2H = C_2H_6O$.

Aldehyde and hydrogen produce ethyl alcohol.

By a repetition of the above processes we may pass to the tricarbon or propyl group.

DIATOMIC ALCOHOLS AND THEIR PRINCIPAL DERIVATIVES.

The general formula for these alcohols is C_nH_{2n}, as seen in ethylene, C_2H_4. They are non-saturated compounds, two of the combining atoms of the carbon being unsatisfied. These bodies directly unite with two atoms of chlorine, iodine, and bromine, to form saturated compounds. CH_2, the lowest term of this series, and which has been termed Methylene, has never been isolated; but its iodide, CH_2I_2, is known. The corresponding diatomic alcohol is unknown; but the diacetate has been obtained.

ETHYLENE, C_2H_4, or **OLEFIANT GAS**. This substance has been already described* in earlier pages. It combines directly with chlorine to form a substance called

ETHYLENE DICHLORIDE, $C_2H_4Cl_2$, which is insoluble in water, but is dissolved by ether and alcohol, and with chlorine forms numerous substitution products by the replacement of one, two, three, or four atoms of hydrogen. Thus—

$C_2H_4Cl_2$; $C_2H_3Cl_3$; $C_2H_2Cl_4$; C_2HCl_5 ; C_2Cl_6.

These bodies are isomeric with a series of chlorine substitution products obtained from ethyl chloride.

ETHYLENE ALCOHOL, or GLYCOL, $C_2H_6O_2$, or $\left.\begin{matrix} C_2H_4 \\ H_2 \end{matrix}\right\} O_2$, is built upon the type of two molecules of water, two hydrogen atoms being replaced by the dyad radical, Ethylene (C_2H_4). It is a thick liquid, sweetish to the taste, without odour or colour; soluble in water and alcohol, and is prepared by acting upon the dibromide of ethylene ($C_2H_4Br_2$) with acetate of silver ($AgC_2H_3O_2$). Thus—

(*a*) $C_2H_4Br_2 + 2AgC_2H_3O_2 = 2AgBr + C_2H_4(C_2H_3O_2)_2$.

Bromide of silver and diacetate of glycol are formed. Again—

(*b*) $C_2H_4(C_2H_3O_2)_2 + BaH_2O_2 = Ba(C_2H_3O_2)_2 + C_2H_6O_2$.

Diacetate of glycol and barium hydroxide yield diacetate of barium and glycol.

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* Part I.

Glycollic Acid, $C_2H_4O_3$, is obtained by the exposure of glycol to air and platinum black, oxygen being absorbed. Thus—

$$C_2H_6O_2 + 2O = H_2O + C_2H_4O_3.$$

When glycol is heated with caustic potash to 240°C., hydrogen and oxalate of potassium are produced. Thus—

$$C_2H_6O_2 + 2KHO = 8H + K_2C_2O_4.$$

It will thus be observed that glycollic and oxalic acids bear the same relation to glycol as acetic acid does to ethyl alcohol.

Glyoxal, $C_2H_2O_2$, is an aldehyde formed from glycol by the loss of four atoms of hydrogen.

Glycol forms two acids, and two chlorides, etc. When hydrochloric acid (HCl) acts upon glycol, the first substance produced is **Glycol Chlorhydrine**, *i.e.*, glycol in which the monad group, HO, is replaced by one atom of chlorine. Thus—

$$\left.\begin{matrix}C_2H_4\\H_2\end{matrix}\right\}O_2 = \text{Glycol.} \qquad \left.\begin{matrix}C_2H_4\\H\end{matrix}\right\}\begin{matrix}O\\Cl\end{matrix} = \text{Glycol Chlorhydrine.}$$

By the further action of chlorine a second atom of hydrogen is replaced, and ethylene chloride, $C_2H_4Cl_2$ results.

Glycol forms a Mono-Acetate and a Di-Acetate. Mono-Ethyl Glycol and Di-Ethyl Glycol also exist.

Ethylene Oxide, C_2H_4O, is a volatile, colourless liquid, which is formed when potash acts upon glycol chlorhydrine.

By the direct union of C_2H_4O with 2H, Alcohol, C_2H_6O, is formed.

Polyethylene Glycols are constructed upon the types of 3, 4, 5, 6, etc., molecules of H_2O; several molecules of C_2H_4 being substituted for the hydrogen equivalent. Thus—

$$\left.\begin{matrix}C_2\overset{\text{II}}{H_4}\\C_2\overset{\text{II}}{H_4}\\H_2\end{matrix}\right\}O_3 = \begin{matrix}\text{Di-Ethylene}\\\text{Glycol.}\end{matrix} \qquad \left.\begin{matrix}C_2\overset{\text{II}}{H_4}\\C_2\overset{\text{II}}{H_4}\\H_2\end{matrix}\right\}O_4 = \begin{matrix}\text{Tri-Ethylene}\\\text{Glycol.}\end{matrix}$$

$$\left.\begin{matrix}C_2\overset{\text{II}}{H_4}\\C_2\overset{\text{II}}{H_4}\\H_2\overset{\text{II}}{C_4}\\C_2\overset{\text{II}}{H_4}\end{matrix}\right\}O_5 = \text{Tetra-Ethylene Glycol.}$$

Ethylene Diamines are volatile bodies, prepared by the action of ammonia upon dibromide of ethylene, and are founded upon the type of two molecules of ammonia ($2NH_3$), 2, 4, or 6 atoms of hydrogen being replaced by ethylene.

They may be primary, secondary, or tertiary, corresponding to the monamines already described.

HIGHER DIATOMIC ALCOHOLS AND THEIR DERIVATIVES.

The higher carbon series give rise to olefines corresponding to ethylene.

* Table of Olefines.

Ethylene	C_2H_4	Octylene	C_8H_{16}
Propylene	C_3H_6	Decatylene (Diamylene) ...	$C_{10}H_{20}$
Butylene	C_4H_8		
Amylene	C_5H_{10}	Cetene	$C_{16}H_{32}$
Hexylene	C_6H_{12}	Cerotene	$C_{27}H_{54}$
Heptylene	C_7H_{14}	Melene	$C_{30}H_{60}$

* Table of Glycols.

Ethylene Alcohol ...	$C_2H_6O_2$	Amylene Alcohol ...	$C_5H_{12}O_2$
Propylene Alcohol ...	$C_3H_8O_2$	Hexylene Alcohol ...	$C_6H_{14}O_2$
Butylene Alcohol ...	$C_4H_{10}O_2$	Octylene Alcohol ...	$C_8H_{18}O_2$

DIATOMIC ACIDS PRODUCED BY THE OXIDATION OF THE GLYCOLS.

Two series of these acids exist—one derived by the replacement of two atoms of hydrogen in the ethylene by one atom of oxygen, and the other by the replacement of all the four atoms of hydrogen in ethylene by two atoms of oxygen. The former of these is termed the Lactic Acid Series, the latter the Oxalic Acid Series.

The following shows the relation of glycol to glycollic and oxalic acids.

$$\left.\begin{matrix}C_2\overset{II}{H_4}\\ H_2\end{matrix}\right\}O_2 \quad ; \quad \left.\begin{matrix}C_2\overset{II}{H_2}O\\ H_2\end{matrix}\right\}O_2 \quad ; \quad \left.\begin{matrix}C_2\overset{II}{O_2}\\ H_2\end{matrix}\right\}O_2.$$

Glycol. Glycollic Acid. Oxalic Acid.

The succeeding series of acids also exists, of which the following are the most important members :

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* These tables contain a complete list of the olefines and glycols as far as they have been prepared.

GENERAL FORMULA, $C_nH_{2n}O_3$.	LACTIC ACID SERIES. (*Monobasic*).
CH_2O_3	Carbonic Acid.
$C_2H_4O_3$	Glycollic Acid.
$C_3H_6O_3$	Lactic Acid.

GENERAL FORMULA, $C_nH_{2n-2}O_4$.	OXALIC ACID SERIES. (*Dibasic*).
$C_2H_2O_4$	Oxalic Acid.
$C_3H_4O_4$	Malonic Acid.
$C_4H_6O_4$	Succinic Acid.

CARBONIC ACID, H_2CO_3. This acid is known only in its salts. The hydrate has never been prepared.

The radical CARBONYL (CO) is supposed to be contained in these salts. As may be seen from its formula, carbonic acid contains only two atoms of replaceable hydrogen; it may be written thus—OH,CO,HO, both the hydroxyl molecules being connected with the group CO.

Two sets of carbonates are known:

The Normal Potassium Carbonate, OK,CO,KO, or K_2CO_3.
The Hydrogen Potassium Carbonate, OH,CO,KO, or $HKCO_3$.

GLYCOLLIC ACID, $C_2H_4O_3$, may be prepared as a crystalline deliquescent mass by the oxidation of glycol, or by the action of liquor potassæ (KHO) upon potassium monochloracetate ($KClC_2H_2O_2$). Thus—

$$KClC_2H_2O_2 + KHO = KCl + KC_2H_3O_3.$$

Chloride of potassium and glycollate of potassium are formed.

An Amide (glycollamide) and an Isomer (glycocoll) also exist.

OXALIC ACID, $C_2H_2O_4$, is found in the juice of many plants as oxalate of lime or potassium. It may be prepared by the following methods:

(1) *Synthetically*, by heating together metallic sodium (Na) and carbonic anhydride (CO_2) to 350°C. Thus—

$$2Na + 2CO_2 = Na_2C_2O_4 \text{ or oxalate of sodium.}$$

(2) By the action of nitric acid upon sugar.

(3) By the action of caustic potash upon sawdust, an oxalate of potassium resulting; from this salt oxalate of lime is obtained, sulphuric acid being subsequently added, with the formation of sulphate of lime and oxalic acid. When heated to 160°C., oxalic acid speedily decomposes, with the formation of carbonic monoxide, carbonic dioxide, and

formic acid. It is dibasic, and forms the following classes of salts:

(1) Normal or Neutral Potassium Oxalate, $K_2C_2O_4 + H_2O$.
(2) Hydric or Acid Potassium Oxalate ... $KHC_2O_4 + H_2O$.
(3) Potassium Quadroxalate ... ... $KH_3(C_2O_4)_2 + 2H_2O$.

When oxalic acid is distilled with methyl or ethyl alcohols. the oxalates of these radicals are respectively obtained.

OXAMIDE is obtained as a white powder by the action of heat upon neutral oxalate of ammonium, $(NH_4)_2C_2O_4$, two molecules of water being removed. Thus—

$$(NH_4)_2C_2O_4 - 2H_2O = (NH_2)_2C_2O_2.$$

This substance may be looked upon as two molecules of ammonia, $\left.\begin{matrix}H_2\\H_2\\H_2\end{matrix}\right\}N_2$, in which two atoms of hydrogen are replaced by C_2O_2.

OXAMIC ACID is prepared by heating the hydric ammonium oxalate $(HNH_4C_2O_4)$. The formula for this acid is $NH_3C_2O_3$.

LACTIC ACID, $C_3H_6O_3$, is contained in sour milk, and is formed from sugar during the so-called *Lactic Fermentation*. It may be prepared, among other methods, by allowing hydrocyanic acid (HCN), hydrochloric acid (HCl), ethyl aldehyde (C_2H_4O), and water (H_2O) to remain in contact for some days. Thus—

$$HCN + HCl + C_2H_4O + 2H_2O = NH_4Cl + C_3H_6O_3.$$

Chloride of ammonium and lactic acid are formed.

This substance is a syrupy liquid, which, when heated, forms an anhydride, LACTIDE, $C_3H_4O_2$, and an acid termed DILACTIC, $C_6H_{10}O_5$. The lactates are all soluble in alcohol and water, and are a well-defined class of salts, which generally contain one atom of a metal, the other hydrogen atom being replaceable only by an organic radical. In this way we have ETHYL LACTIC ACID, $C_2H_5,H,C_3H_4O_3$, and

ZINC LACTATE, $Zn(C_3H_5O_3)_2,3H_2O$. This substance crystallises in long shining needles.

LACTAMIDE, $C_3H_7O_2N$, is a substance obtained by acting upon lactide with ammonia.

It is the isomer of ALANINE, which is formed by the combination of water, aldehyde, and hydrocyanic acid.

Alanine is decomposed by nitrous acid (HNO_2). Thus—

$$C_3H_7O_2N + HNO_2 = H_2O + 2N + C_3H_6O_3.$$

Water, nitrogen, and lactic acid are formed.

LACTYL CHLORIDE, $C_3H_4OCl_2$, is obtained by acting upon lactate of calcium with pentachloride of phosphorus.

Sarco-lactic or Para-lactic Acid bears a close resemblance to lactic acid, with which it is isomeric. It exists in muscular tissue. The two acids are distinguished by the difference in their crystalline form and in the solubility of their salts.

Succinic Acid, $C_4H_6O_4$, occurs in wormwood, amber, certain resins, and in small quantity in some animal juices. It may be obtained by distilling amber. It may also be artificially prepared by the oxidising agency of nitric acid upon butyric acid ($C_4H_8O_2$). Thus—

$$C_4H_8O_2 + 3O = H_2O + C_4H_6O_4.$$

Water and succinic acid are formed.

This acid forms, when heated with phosphorus pentachloride, both a chloride and an anhydride. Bromine substitution products are likewise known, viz.: $C_4H_5BrO_4$, Monobrom-Succinic Acid; and $C_4H_4Br_2O_4$, Dibrom-Succinic Acid. These last acids, when acted upon by silver oxide and water, respectively form malic and tartaric acids.

Succinic acid is dibasic, and forms two classes of salts. The salts formed with the alkaline metals are soluble, and yield insoluble brown precipitates with the persalts of iron.

Succinic Anhydride, $C_4H_4O_3$, also exists.

Succinamide, $C_4H_4O_2(H_2N)_2$, and Succinimide, $C_4H_4O_2HN$, are the ammonia derivatives of succinic acid.

Iso-Succinic Acid is isomeric with succinic acid, and may be obtained by the action of potash upon cyano-propionic acid ($C_3H_5(CN)O_2$).

Malic Acid, $C_4H_6O_5$, occurs in the juice of nearly all fruits—in mountain ash berries and garden rhubarb. Although a triatomic acid, still only two of its three typical hydrogen atoms are replaceable by a metal; it therefore acts as if it were dibasic. All malates are soluble in water. If malic acid be heated to 180°C., water (H_2O) is lost, and a new acid is formed, $C_4H_4O_4$, existing in two isomeric conditions, viz.: as maleic and fumaric acids. By the direct union of these acids with hydrogen, succinic acid is produced.

Tartaric Acid, $C_4H_6O_6$, resides in the juice of such fruits as the tamarind and grape. It is deposited as argol, or acid tartrate of potash, in wine casks during the fermentation of grape juice. There are several isomeric conditions of tartaric acid, viz.:

(1) The ordinary or Dextro-Tartaric Acid, by which the plane of polarisation is turned to the right.

(2) The Inactive or Racemic Acid, which does not affect the polarised ray in any way. This may be divided into—

(*a*) DEXTRO-TARTARIC ACID, or the common acid.

(*b*) LÆVO-TARTARIC ACID. Deviating the polarised plane to the left.

Tartaric acid may be prepared by the action of nitric acid upon sugar of milk. It is dibasic, or contains two atoms of hydrogen which are replaceable by metals. Thus there are two classes of tartrates, viz.:

Neutral Potassium Tartrate, $\left.\begin{matrix}K\\K\end{matrix}\right\}C_4H_4O_6$.

Hydric or Acid Potassium Tartrate, $\left.\begin{matrix}K\\H\end{matrix}\right\}C_4H_4O_6$.

The Dextro-Tartaric acid decomposes when heated to 180°C., giving out the odour of caramel. When exposed to oxidising agents it is converted into carbonic, oxalic and formic acids; and when fused with caustic potash, acetic and oxalic acids result. With *antimony, tartaric acid forms tartar emetic ($KSbOC_4H_4O_6$).

A solution of tartaric acid gives, when added in excess to a moderately strong solution of a potassium salt, a white crystalline precipitate of cream of tartar, falling slowly.

Silver nitrate produces in neutral tartrates a white precipitate of tartrate of silver, soluble in liquor ammoniæ; and upon gently heating the solution, a bright metallic deposit of silver is formed.

CITRIC ACID, $C_6H_8O_7$, is tribasic, and occurs in the juice of the citrus limetta (the lime) and the lemon, and in many other fruits, along with malic acid.

There are three series of citrates, in which one, two, or three atoms of hydrogen may be replaced by a metal. The citrates of the alkaline-earth metals, of silver and of lead, are insoluble in water, but those of the alkaline metals are soluble.

CYANOGEN AND ITS COMPOUNDS.†

The following are the most important of the compounds containing the monad radical cyanogen (CN or Cy), viz.:

Cyanogen Gas,	$\left.\begin{matrix}CN\\CN\end{matrix}\right\}$.	Hydrocyanic Acid,	$\left.\begin{matrix}H\\CN\end{matrix}\right\}$.
Cyanogen Chloride,	$\left.\begin{matrix}Cl\\CN\end{matrix}\right\}$.	Cyanic Acid,	$\left.\begin{matrix}H\\CN\end{matrix}\right\}O$.
Cyanamide,	$\left.\begin{matrix}CN\\H\\H\end{matrix}\right\}N$.	Sulphocyanic Acid,	$\left.\begin{matrix}H\\CN\end{matrix}\right\}S$.

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* Part II.

† Part I.

All the compounds of cyanogen may be regarded as derived from ammonia. Cyanic acid often behaves as if it were CO,HN, and thus shows a connection with the oxalic acid series. Many polymeric modifications are observed among the cyanogen compounds; for there is a liquid chloride of cyanogen, CN,Cl; a solid chloride, 3CNCl; cyanic acid is HCNO, and cyanuric acid is 3HCNO.

Cyanogen Gas, Dicyanogen, $(CN)_2$, s found in small quantities in the gas of the iron-blast furnace. It may be formed by heating oxalate of ammonium and oxamide.

When cyanogen is mixed with potash, cyanate and cyanide of potassium are formed.

Hydrocyanic or Prussic Acid, HCN. This substance has lately been prepared by the direct union of acetylene (C_2H_2) with nitrogen (N), a series of electric sparks being passed through those gases. Thus—

$$C_2H_2 + 2N = 2HCN.$$

This acid readily decomposes by water into formiate of ammonium. Thus—

$$HCN + 2H_2O = NH_4CHO_2.$$

Both simple and double cyanides exist. Amongst the simple cyanides are the following:

Cyanide of Potassium. This may be formed by the addition of potash to a watery solution of hydrocyanic acid, or by burning potassium in cyanogen gas. It is generally obtained by the fusion of carbonate of potash (K_2CO_3) with ferrocyanide of potassium ($K_4FeC_6N_6$). Thus—

$$K_2CO_3 + K_4FeC_6N_6 = KCNO + Fe + CO_2 + 5KCN.$$

Cyanate of potash, iron, carbonic anhydride and cyanide of potassium result.

This is a white substance and a violent poison. It is extensively used in photography in order to dissolve the unaltered salts of silver, a double salt of potassium and silver resulting (KCN + AgCN). It is also employed in the electrotyping of silver and gold, in which process it dissolves these metals.

Percyanide of Mercury, HgC_2N_2, is formed by dissolving peroxide of mercury in aqueous hydrocyanic acid. When heated it yields cyanogen gas, metallic mercury, and a black substance termed Paracyanogen, an isomer of cyanogen gas.

Cyanide of Silver, AgCN, is a white salt, soluble in boiling nitric acid.

Cyanide of Copper, CuCN, is a brownish red salt.

Cyanic Acid, HCNO, is monobasic, and forms salts called *Cyanates*. It is formed either by the direct oxidation of cyanides, or by acting upon potash with cyanogen gas. It is impossible to prepare free cyanic acid from its salts, since it instantly decomposes into its polymers, *Cyamelide* and *Cyanuric Acid*, 3HCNO, or by combining with water is converted into *Urea* (CH_4N_2O) and *Carbonic Anhydride* (CO_2).

By heating cyanuric acid in a retort, a colourless mobile liquid, consisting of volatile cyanic acid, is given off, and may be collected in a freezing mixture; but when removed from such a mixture it immediately changes into solid cyamelide.

In aqueous solution cyanic acid instantly combines with water to form Di-Carbonate of Ammonia. Thus—

$$HCNO + 2H_2O = NH_4HCO_3.$$

With ammonia (NH_3) cyanic acid forms urea. Thus—

$$NH_3 + HCNO = CH_4N_2O.$$

Fulminic Acid, $C_2H_2N_2O_2$, is obtained as fulminate of silver by the action of nitrous acid (HNO_2) upon metallic silver (Ag) and nitrite of ethyl (C_2H_5,NO_2). Thus—

$$2Ag + C_2H_5,NO_2 + HNO_2 = 2H_2O + Ag_2,C_2N_2H_2O_2.$$

Water and fulminate of silver result.

Cyanuric Acid, $H_3C_3N_3O_3$, is a crystalline substance, formed when urea is heated or when water is added to solid chloride of cyanogen. It is tribasic, and formed upon the type of 3 molecules of water—

$$\left.\begin{matrix}H_3\\H_3\end{matrix}\right\}O_3 = \text{Water}; \quad \left.\begin{matrix}(CN)_3\\H_3\end{matrix}\right\}O_3 = \text{Cyanuric Acid}.$$

Cyanate of Ammonia, NH_4CNO, is formed when cyanic acid and dry ammonia are brought together.

This salt is remarkable from the fact that at 100°C. it at once becomes urea. Thus—

$$NH_4CNO = CH_4N_2O.$$

This molecular change will also take place, although gradually, at ordinary temperatures.

UREA, CARBAMIDE, CH_4N_2O.

This substance may be regarded as built upon two molecules of ammonia in which two of the hydrogen atoms are replaced by carbonic oxide (CO). Thus—

$$\left.\begin{matrix}H_2\\H_2\\H_2\end{matrix}\right\}N_2 = \text{Ammonia.} \qquad \left.\begin{matrix}CO\\H_2\\H_2\end{matrix}\right\}N_2 = \text{Urea.}$$

It may be prepared artificially in the following modes:

(1) By heating ferrocyanide of potassium (K_4FeCy_6) with black oxide of manganese (MnO_2); cyanate of potassium

(KCNO) is formed, to which, when dissolved in water, sulphate of ammonia (NH_4SO_4) is added in order to convert it into cyanate of ammonium (NH_4CNO). After evaporating to dryness the urea may be extracted by alcohol. Thus again—

$$NH_4CNO = CH_4N_2O.$$

(2) By the addition of ammonia (NH_3) to carbonate of ethyl $(C_2H_5)_2CO_3$. Thus—

$$(C_2H_5)CO_3 + 2NH_3 = C_2H_5HO + CH_4N_2O.$$

Ethyl alcohol and urea are formed.

(3) By acting upon red mercuric oxide (HgO) with oxamide ($C_2H_4N_2O_2$). Thus—

$$C_2H_4N_2O_2 + HgO = Hg + CO_2 + CH_4N_2O.$$

Metallic mercury, carbonic anhydride and urea are formed.

Urea is soluble in its own weight of cold water; when heated with water to 100°C. in closed tubes it decomposes into ammonia and carbonic anhydride, and at a higher temperature cyanuric acid ($C_3N_3H_3O_3$) is formed. It is also immediately decomposed by nitrous acid into water, nitrogen and carbonic anhydride. The most important salts of urea are the oxalate and nitrate. When mercuric oxide is added to urea an insoluble compound is formed, by which the quantity of urea in a solution is estimated.

Compound Ureas are formed by the action of cyanic acid upon a compound ammonia. These may be regarded as urea in which one or more of the hydrogen atoms are replaced by methyl, ethyl, propyl, etc. They sometimes contain oxidised radicals, as acetyl, butyryl, etc.

FERROCYANOGEN (hypothetical), FeC_6N_6 or FCy.

Hydroferrocyanic Acid, $H_4FeC_6N_6$ or HFCy, is a tetrabasic acid, occurring in white scales, which become blue on exposure, from the absorption of oxygen. This acid may be formed by the addition of hydrochloric acid (HCl) to a strong solution of ferrocyanide of potassium ($K_4FeC_6N_6$). Thus—

$$K_4FeC_6N_6 + 4HCl = 4KCl + H_4FeC_6N_6.$$

Chloride of potassium and hydroferrocyanic acid are formed.

Ferrocyanide of Potassium, or yellow prussiate of potash, $K_4FeC_6N_6 + 3H_2O$, is obtained from horns, hide-parings, old iron, and carbonate of potash. Thus—

$$6KCNS + 6Fe = K_2S + 5FeS + K_4FeC_6N_6.$$

Sulphocyanide of potassium and iron yield sulphide of potassium, sulphide of iron and ferrocyanide of potassium.

The sulphur is derived from the tissues employed.

This salt acts as a mild purgative, but possesses no poisonous properties. When exposed to strong heat, it yields carbide of iron and cyanide of potassium, and it forms hydrocyanic acid when heated with sulphuric acid.

Ferrocyanide of potassium gives with the salts of—

1. Cobalt, *yellowish-green* precipitates in acid solutions.
2. Uranium, *brown* ,, ,, ,,
3. Copper, *chocolate* ,, ,, ,,
4. Barium, *yellowish-white* ,, ,, ,,
5. { Zinc, Nickel, Tin, Cadmium, Lead, Antimony, Bismuth, Silver, Mercury, Manganese, } *white* precipitates in acid solutions.
6. Ferrous Salts, white precipitates, passing through *light-blue* to dark-blue.
7. Ferric Salts, *dark* (*Prussian*) *blue.*

Ferrocyanide of Potassium and Iron, or Everitt's Yellow Salt, K_2FeFcy, is formed during the preparation of prussic acid from sulphuric acid and ferrocyanide of potassium.

Ferric Ferrocyanide, or Ordinary Prussian Blue, $Fe_4Fcy_3 18H_2O$, is obtained by the addition of a ferric salt to ferrocyanide of potassium. It occurs in blue irregular masses, which, when rubbed with the finger-nail, leave a copper-coloured line. When heated, and flame added, it burns like tinder.

FERRICYANOGEN (hypothetical), $FeCy_6$ or Fdcy.

Hydroferricyanic Acid, H_3FeCy_6, is tribasic, occurring in dark brownish-green needles. It is prepared by the addition of hydrochloric acid to the following salt :

Ferricyanide of Potassium, or Red Prussiate of Potash, K_3FeCy_6. This substance is met with in ruby-red crystals, which, when placed in a candle flame, emit bright sparks. It is prepared by passing a stream of chlorine gas through the yellow prussiate of potash.

Ferricyanide of potassium gives, in neutral solutions, the following precipitates with the salts of—

1. Zinc, *orange.*
2. Cadmium, *yellow.*
3. Nickel, *yellowish-green.*
4. Cobalt, *reddish-brown.*
5. Ferrous, *bright-blue.*
6. Ferric, *none.*
7. Copper, *yellowish-green.*
8. Manganous, *brown.*
9. Stannous, *white.*
10. Silver, *orange.*
11. Mercurous, *brownish-red.*

These precipitates are all insoluble in hydrochloric acid, except in the case of tin and zinc.

Ferrous Ferricyanide, or **Turnbull's Blue**, $Fe_3(FeCy_6)_2 + H_2O$, is a valuable brilliant blue salt, obtained by the addition of ferrous sulphate to ferricyanide of potassium.

Ferrous Potassium Ferricyanide, or **Williamson's Blue**, $FeK(FeCy_6) + H_2O$, is a valuable pigment, obtained by boiling Everitt's yellow salt with nitric acid.

NITROCYANOGEN (hypothetical), $Fe_2Cy_{10}N_2O_3$.

Hydronitro-Prussic Acid, $H_4Fe_2Cy_{10},N_2O_3$, may be obtained as the

Sodium-Potassium Nitro-Prusside, by adding together ferrocyanide of potassium, perchloride of mercury, nitrite of sodium and acetic acid.

Sodium Nitro-Prusside, $Na_4Fe_2Cy_{10}N_2O_3,4H_2O$, may be obtained in ruby-red prisms by adding together ferrocyanide of potassium, nitric acid, carbonate of soda and water.

The nitro-prussides yield the following precipitates with the salts of—

1. Copper, *pale-green.*
2. Zinc, *salmon-coloured.*
3. Silver, *flesh-coloured.*
4. Ferrous salts, *salmon-coloured.*
5. Nickel, *dirty-white.*
6. Cobalt, *flesh-coloured.*
7. Lead, Mercury, Tin, and Ferric Salts. *none.*
8. A *magnificent deep purple* is produced with the faintest trace of an alkaline sulphide.

SULPHOCYANOGEN (hypothetical), CNS or Scy.

Hydrosulphocyanic Acid, HCNS or HScy, is a colourless, pungent, poisonous oily liquid, with an acid taste. It is obtained as the potassium salt by heating ferrocyanide of potassium (K_4FeCy_6) with sulphur (S), sulphocyanide of potassium (KScy) being formed, or

By the action of sulphuretted hydrogen (H_2S) upon sulphocyanide of mercury ($Hg(Scy)_2$). Thus—

$$Hg(Scy)_2 + H_2S = HgS + 2HScy.$$

Sulphide of mercury and sulphocyanic acid are formed.

Potassium Sulphocyanide, KCNS, occurs in deliquescent colourless non-poisonous crystals.

The sulphocyanides yield the following precipitates with salts of—

1. Mercury, copper, silver and gold, *white.*
2. Acetate of lead, *white.*
3. Ferric salts, *blood-red.*

COBALTICYANOGEN (hypothetical) $CoCy_6$.

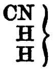
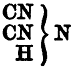
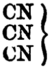
Hydrocobalticyanic Acid, H_3CoCy_6, is prepared by the action of sulphuretted hydrogen upon cobalticyanide of copper.

Potassium Cobalticyanide, K_3CoCy_6, occurs in yellow flattened prisms.

Cobalticyanides give the following precipitates with the salts of—

1. Nickel, *pale-blue*, gelatinous.
2. Cobalt, *pale-red.*
3. Copper, *pale-olive.*
4. Zinc, *white.*
5. Lead, *none.*
6. Silver, Ferrous, Manganous, Stannous, and Mercurous, *white.*

Amongst the substances formed by the action of chloride of cyanogen upon ammonia are the following, viz.:

Cyanamide,

$$\left.\begin{matrix}CN\\H\\H\end{matrix}\right\}N;$$
Dicyanamide,

$$\left.\begin{matrix}CN\\CN\\H\end{matrix}\right\}N;$$
Tricyanamide,

$$\left.\begin{matrix}CN\\CN\\CN\end{matrix}\right\}N.$$

CARBONYL AND SULPHOCARBONYL COMPOUNDS.

Carbonyl, CO, is a dyad radical, known in the free state as Carbonic Oxide Gas.

The following are derived from CO, viz.:

$CO.O$, Carbon Dioxide.
$CO.S$, Carbonyl Sulphide.
$COCl_2$, Carbonyl Chloride.
$CO(OK)_2$, Potassium Carbonate.
$CO(NH_2)_2$, Carbamide.

Carbonyl Chloride, $COCl_2$, is sometimes known as Phosgene Gas. It is a colourless gas, having a suffocating smell, and is formed by bringing together dry chlorine and dry carbonyl gases in the sunlight. CO forms with sulphur vapour, carbonyl sulphide, COS, and with caustic potash, formiate of potash, KCOHO.

Carbamic Acid, NH_2COHO, is only known in combination. Carbamate of ammonium may be obtained by adding together dry ammonia gas and carbon dioxide.

The existence of a dyad radical, **Sulphocarbonyl**, CS, is assumed in the sulphocarbonyl compounds, but it is not known in the free state.

Sulphocarbonic Acid, $CS(HS)_2$. Carbon disulphide unites with metallic sulphides, with the formation of sulphocarbonates; thus, by dissolving carbon disulphide in a solution of sulphide of potassium, sulphocarbonate of potassium is formed. This acid is a heavy brown oil, obtained by adding hydrochloric acid to an alkaline sulphocarbonate.

Sulphocarbamide or **Sulphur Urea**, $CS(NH_2)_2$, may be prepared by heating sulphocyanide of ammonium to 170°C. It forms salts with acids, and crystallizes in long colourless needles.

Uric Acid, $C_5H_4N_4O_3$, is a bibasic acid, and its salts are soluble, the lithium urates being especially so. It is contained in the human urine, and abundantly in the urine of serpents, birds, etc.

Among the numerous derivatives of uric acid are the following:

Alloxan, $C_4H_2N_2O_4$; **Alloxatine**, $C_8H_4N_4O_7$;
Dialuric Acid, $C_4H_4N_2O_4$; **Murexide**, $C_8H_4(NH_4)N_5O_6$.
Parabanic Acid, $C_3H_2N_2O_3$.

By murexide a beautiful purple solution is formed.

The above are usually looked upon as *Amides*, all containing C_2O_2 (the radical of oxalic acid).

Creatin, $C_4H_9N_3O_2 + H_2O$, is obtained by the oxidation of nitrogenous animal tissues, and is found in small quantities in the urine and in muscular tissues. In contact with baryta water it is converted into urea (CH_4N_2O) and sarcosine ($C_3H_7NO_2$). This substance (sarcosine) may be obtained by the action of methylamine upon monochloracetic acid, and is therefore methyl glycocoll.

Creatinine, $C_4H_7N_3O$. This substance differs from creatin by containing one molecule less of water. It forms well-crystallised salts with acids, is found in muscular tissue, and crystallises in colourless prisms, the solution of which is strongly alkaline.

TRIATOMIC ALCOHOLS AND THEIR DERIVATIVES.

The hydrocarbon group of the general formula, C_nH_{2n-1}, act as triatomic radicals, and to these the generic name of **Glycerines** is applied, by reason of the special name of one of the series, viz.:

Glycerine $= \left.\begin{matrix}C_3H_5\\H_3\end{matrix}\right\}O_3$. From this formula it appears that glycerine is built upon the type of three molecules of water and contains three hydrogen atoms, each of which may be replaced by a metal.

The following table shows the simplicity of the relation, in composition, between the mono- di- and tri- atomic alcohols of the same carbon series:

$$C_3H_7H \qquad\qquad = \text{Propyl Hydride.}$$

$$\left.\begin{matrix}C_3H_7\\H\end{matrix}\right\}O = C_3H_8O = \text{Monatomic Propyl-Alcohol.}$$

$$\left.\begin{matrix}C_3\overset{\text{II}}{H}_6\\H_2\end{matrix}\right\}O_2 = C_3H_8O_2 = \text{Diatomic Propyl-Glycol.}$$

$$\left.\begin{matrix}C_3\overset{\text{III}}{H}_5\\H_3\end{matrix}\right\}O_3 = C_3H_8O_3 = \text{Triatomic Propyl-Glycerine.}$$

No glycerines of the mono- and di- carbon series have as yet been prepared. Amyl Glycerine, or the glycerine of the penta-carbon series, has been obtained.

GLYCERINE = $\left.\begin{matrix}C_3H_5\\H_3\end{matrix}\right\}O_3$. Most oils and fats (vegetable and animal, and consisting of triatomic ethers of the higher fatty acid series) contain this substance.

Beef suet, or STEARINE, is in reality Tri-Stearate of Glycerine, $\left.\begin{matrix}C_3H_5\\(C_{18}H_{35}O)_3\end{matrix}\right\}O_3$, or glycerine in which three molecules of the radical stearyl ($C_{18}H_{35}O$), replace three hydrogen atoms.

The process by which glycerine is obtained from fats is termed—

SAPONIFICATION.

The fat or oil is decomposed by caustic alkali (soda of potash), an alkaline stearate, or soap, is formed, and the glycerine remaining in solution is set free by the addition of common salt after the separation of the soap. To obtain glycerine *pure*, lead oxide may be used to decompose the fat; lead plaister is thrown down, and glycerine remains in solution. The best method, however, is the production of free stearic acid and glycerine by decomposing the fats with high pressure steam.

We may express the above process by the following equation:

Stearate of Glycerine and Alkaline Hydrate yield

$$C_3H_5(C_{18}H_{35}O_2)_3 \quad + \quad 3\left\{\begin{matrix}K\\Na\end{matrix}\right.HO \quad =$$

Alkaline Stearate and Glycerine

$$3\left\{\begin{matrix}K\\Na\end{matrix}\right.C_{18}H_{35}O_2 \quad + \quad C_3H_5(HO)_3.$$

Glycerine is a thick liquid, of syrupy consistence, without colour, and of a sweetish taste. When heated, it yields an irritating vapour termed *Acrolein*, C_3H_4O. It is soluble in water and in alcohol.

When *Diluted Nitric Acid* acts upon glycerine, oxidation takes place, and **Glycerinic Acid**, $\left.\begin{matrix}C_3H_3O\\H_3\end{matrix}\right\}O_3$, is formed by the substitution of O for two atoms of the hydrogen of C_3H_5. Hydriodic acid (HI) reduces glycerine to iso-propyl-iodide. Thus—

$$C_3H_8O_3 + 5HI = 4I + 3H_2O + C_3H_7I.$$

Iodine, water and iso-propyl-iodide are formed.

Hydriodic acid also reduces propyl glycol to the same substance; it is therefore possible to pass from the di- and tri-atomic series of alcohols to the monatomic series of iso-alcohols.

By the action of *Strong Nitric Acid* upon glycerine,

Trinitrin, or **Tri-Nitro-Glycerine** ($C_3H_5(NO_3)_3$), sometimes known by the name of **Nobel's Blasting Oil**, or **Glonoin Oil**, is formed. Thus—

$$C_3H_5(HO)_3 + 3HNO_3 = 3H_2O + C_3H_5(NO_3)_3.$$

Water and nitro-glycerine are formed.

Nitro-glycerine may be written, $\left.\begin{matrix}C_3H_5\\(NO_2)_3\end{matrix}\right\}O_3$; and it will thus be observed that three atoms of the radical NO_2 replace three atoms of hydrogen in glycerine.

Glonoin Oil is employed for blasting purposes, since upon heating it explodes with great violence.

The name **Chlorhydrines** is given to the substances formed when glycerine is heated with hydrochloric acid. These compounds are three in number, and are constituted upon the mixed types of hydrochloric acid and water. Thus—

Mixed types of Water and Hydrochloric Acid.

$\left.\begin{matrix}H_3\\H_3\end{matrix}\right\}O_3$;	$\left.\begin{matrix}\left.\begin{matrix}H_2\\H_2\end{matrix}\right\}O_2\\HCl\end{matrix}\right\}$;	$\left.\begin{matrix}\left.\begin{matrix}H\\H\end{matrix}\right\}O\\(HCl)_2\end{matrix}\right\}$;	H_3Cl_3.
Glycerine	**Chlorhydrine**	**Dichlorhydrine**	**Trichlorhydrine**
$\left.\begin{matrix}C_3H_5\\H_3\end{matrix}\right\}O_3$;	$\left.\begin{matrix}H_2\\C_3\overset{'''}{H}_5\end{matrix}\right\}\left\{\begin{matrix}O_2\\Cl\end{matrix}\right.$;	$\left.\begin{matrix}H\\C_3\overset{'''}{H}_5\end{matrix}\right\}\left\{\begin{matrix}O\\Cl_2\end{matrix}\right.$;	$C_3\overset{'''}{H}_5Cl_3$.

Only three Triatomic Alcohols are described, viz.:

Propenyl Alcohol, $C_3H_5(HO)_3$; **Quintenyl Alcohol**, $C_5H_9(HO)_3$; **Methenyl Alcohol**, $CH(HO)_3$. The last of these has never been isolated, but its ethers are important, being chloroform, etc.

CHLOROFORM, or **METHENYL CHLORIDE**, $CHCl_3$, is a colourless liquid, nearly insoluble in water. It possesses anæsthetic properties, and burns with a greenish flame. The vapour has a specific gravity of 1·48.

Chloroform may be formed—

(1) Together with methene chloride, CH_2Cl_2, when a mixture of gaseous methyl chloride and chlorine are exposed to the sun's rays.

(2) By the action of alkalies on chloral (C_2HCl_3O). Thus—

$$C_2HCl_3O + KHO = KCHO_2 + CHCl_3.$$

Formiate of the alkali and chloroform are produced.

(3) By the action of nascent hydrogen upon carbon tetrachloride (CCl_4). Thus—

$$CCl_4 + 2H = HCl + CHCl_3.$$

Hydrochloric acid and chloroform result.

(4) From ethyl alcohol (C_2H_5HO), and chlorinated lime ($CaCl_2O_2$). Thus—

$$2C_2H_5HO + 5CaCl_2O_2 = 2CaCO_3 + 2CaCl_2 + CaH_2O_2 + 4H_2O + 2CHCl_3.$$

Carbonate of lime, chloride of calcium, slaked lime, water and chloroform are formed.

(5) Chloroform is made on a large scale by the cautious distillation of water and alcohol with good commercial chloride of lime. The oily portion of the distillate consists of chloroform, which may be purified by agitation with water, dessication with chloride of calcium and distillation in a water bath.

The *detection of chloroform in a fluid* is performed as follows:

The fluid is placed in a test tube and heated; chlorine and hydrochloric acid gases are formed, which will give (1) *white* precipitates with nitrate of silver, and (2) a *blue* colour with starch and iodide of potassium.

BROMOFORM, $CHBr_3$, is a heavy volatile liquid, with a specific gravity of 2·9. It is analogous to chloroform, and is prepared by adding together ethyl alcohol, potash, and bromine. Thus—

$$C_2H_5HO + 6KHO + 8Br = 5KBr + KCHO_2 + 5H_2O + CHBr_3.$$

Bromide of potassium, formiate of potash, water and bromoform are produced.

IODOFORM, CHI_3, is a yellow crystalline solid, having a strong odour of saffron. It is formed by adding together alcohol, potash and iodine. Thus—

$$C_2H_5HO + 6KHO + 8I = 5KI + KCHO_2 + 5H_2O + CHI_3.$$

Iodide of potassium, formiate of potash, water and iodoform result.

THE ACETINS OR GLYCERIN ETHERS OF THE FATTY ACIDS.

These substances in their constitution resemble the fats. They are thick oily liquids, boil at a high temperature, and are only slightly soluble in water. They are obtained by the action of glacial acetic acid upon glycerine. They are the following:

MONO-ACETIN. DI-ACETIN. TRI-ACETIN.

$$\left.\begin{matrix}H_2\\C_3H_5\\C_2H_3O\end{matrix}\right\}O_3;\qquad \left.\begin{matrix}H\\C_3H_5\\(C_2H_3O)_2\end{matrix}\right\}O_3;\qquad \left.\begin{matrix}C_3H_5\\(C_2H_3O)_3\end{matrix}\right\}O_3.$$

THE PALMITINS, STEARINS AND OLEINS, OR PALMITIC, STEARIC AND OLEIC ETHERS OF GLYCERIN.

PALMITINS are crystalline fats, and are the following:

MONO-PALMITIN. DI-PALMITIN. TRI-PALMITIN.

$$\left.\begin{matrix}H_2\\C_3H_5\\C_{16}H_{31}O\end{matrix}\right\}O_3;\qquad \left.\begin{matrix}H\\C_3H_5\\(C_{16}H_{31}O)_2\end{matrix}\right\}O_3;\qquad \left.\begin{matrix}C_3H_5\\(C_{16}H_{31}O)_3\end{matrix}\right\}O_3.$$

The first and second are obtained by heating glycerine with palmitic acid ($C_{16}H_{32}O_2$) in sealed tubes; the third by heating a mixture of one part of mono-palmitin with ten parts of palmitic acid.

STEARINS can be artificially prepared by heating stearic acid with glycerine. They are the following:

MONO-STEARIN. DI-STEARIN. TRI-STEARIN.

$$\left.\begin{matrix}H_2\\C_3H_5\\C_{18}H_{35}O\end{matrix}\right\}O_3;\qquad \left.\begin{matrix}H\\C_3H_5\\(C_{18}H_{35}O)_2\end{matrix}\right\}O_3;\qquad \left.\begin{matrix}C_3H_5\\(C_{18}H_{35}O)_3\end{matrix}\right\}O_3.$$

Tri-stearin may be prepared from mutton or beef suet. It forms white shining plates.

The OLEINS are the following:

MON-OLEIN. DI-OLEIN. TRI-OLEIN.

$$\left.\begin{matrix}H_2\\C_3H_5\\C_{18}H_{33}O\end{matrix}\right\}O_3;\qquad\left.\begin{matrix}H\\C_3H_5\\(C_{18}H_{33}O)_2\end{matrix}\right\}O_3;\qquad\left.\begin{matrix}C_3H_5\\(C_{18}H_{33}O)_3\end{matrix}\right\}O_3.$$

They are produced by heating glycerin with oleic acid ($C_{18}H_{34}O_2$) in sealed tubes, in various proportions.

THE ETHYLINS, OR ETHYL GLYCERIN ETHERS,

may be obtained by acting upon ethylate of sodium with the mono-, di-, or tri- chlorhydrins. They are the three following:

MON-ETHYLIN. DI-ETHYLIN. TRI-ETHYLIN.

$$\left.\begin{matrix}H_2\\C_3H_5\\C_2H_5\end{matrix}\right\}O_3;\qquad\left.\begin{matrix}H\\C_3H_5\\(C_2H_5)_2\end{matrix}\right\}O_3;\qquad\left.\begin{matrix}C_3H_5\\(C_2H_5)_3\end{matrix}\right\}O_3.$$

The POLY-GLYCERINS correspond to the polyatomic glycols. Thus—

DI-GLYCERIN. TRI-GLYCERIN.

$$\left.\begin{matrix}H_4\\(C_3H_5)_2\end{matrix}\right\}O_5;\qquad\left.\begin{matrix}H_5\\(C_3H_5)_3\end{matrix}\right\}O_7.$$

NATURAL FATS AND OILS.

These are all compounds of glycerine, especially with palmitic, stearic, or oleic acids. They are met with in the bodies of animals and plants.

FIXED Oils and Fats leave a stain on paper, which cannot be distilled without decomposition. They are insoluble in water, rather soluble in alcohol, and very soluble in ether. They saponify with various oxides, giving up their constituent glycerine. They are divided into—

DRYING, such as linseed, walnut, hemp, and poppy oils;

NON-DRYING, as castor, croton, sperm and colza oils.

VOLATILE or ESSENTIAL Oils are generally colourless, and give odour to leaves, fruits and flowers. They are scarcely soluble in water, but are easily so in alcohol or ether. They communicate to paper a greasy stain, which volatilises when warmed. They do not saponify, and become resinous and coloured by oxidation.

Oleic acid is found in nearly all fats and oils, and the liquid portions of the fats are formed by the compound of this acid with glycerin.

ALLYL COMPOUNDS.

The compounds of an unsaturated monad radical, C_3H_5, or Allyl, are closely connected with glycerine. By acting with glycerine upon phosphorus iodide, allyl iodide (C_3H_5I) is obtained, from which numerous substances have been derived, the aldehyde of the series being Acrolein, a substance produced by the destructive distillation of glycerine.

Allyl Alcohol, C_3H_5HO, is a colourless liquid, with a pungent smell; it is prepared by adding ammonia (NH_3) to allyl oxalate ($(C_3H_5)_2C_2O_4$). Thus—

$$2NH_3 + (C_3H_5)_2C_2O_4 = C_2H_4N_2O_2 + 2C_3H_5HO.$$

Oxamide and allyl alcohol are formed.

Di-Allyl Ether, $(C_3H_5)_2O$, is formed by the action of sodium allylate (NaC_3H_5O) upon allyl iodide (C_3H_5I). Thus—

$$NaC_3H_5O + C_3H_5I = NaI + (C_3H_5)_2O.$$

Iodide of sodium and di-allyl ether are formed.

Allyl Sulphide, $(C_3H_5)_2S$, occurs in nature as the essential oil of garlic; and

Allyl Sulphocyanide, C_3H_5CNS, as the essential oil of black mustard seed.

Acrolein, C_3H_4O, is the aldehyde of allyl alcohol, and may be produced by the oxidation of that alcohol, or by the abstraction of two molecules of water from glycerine. It is a colourless liquid, with a pungent odour, very irritating to the nose and eyes.

Acroleín rapidly oxidises to Acrylic Acid, $C_3H_4O_2$, a substance closely analogous to acetic acid.

The following series of acids differ from the fatty acid series by containing two atoms less of hydrogen.

Acrylic Acid ...	$C_3H_4O_2$	Pyroterebic Acid	$C_6H_{10}O_2$
Crotonic Acid ...	$C_4H_6O_2$	Hypogæic Acid ...	$C_{16}H_{30}O_2$
Angelic Acid ...	$C_5H_8O_2$	Oleic Acid ...	$C_{18}H_{34}O_2$
Erucic Acid	$C_{22}H_{42}O_2$.		

THE ACETYLENE SERIES OF HYDROCARBONS.

By the action of potash upon the bromides or iodides of the ethylene series, the hydrocarbon of the acetylene series is obtained. Thus—

$$C_2H_4Br_2 + 2KHO = 2H_2O + 2KBr + C_2H_2.$$

Dibromide of ethylene and potash yield water, bromide of potassium and acetylene.

The following is the list of the Acetylene series of Hydrocarbons:

Acetylene	C_2H_2	Hexoylene	C_6H_{10}
Allylene	C_3H_4	Œnanthylidene ...	C_7H_{12}
Crotonylene	C_4H_6	Caprylidene	C_8H_{14}
Valerylene	C_5H_8	Rutylene	$C_{10}H_{18}$
Benylene	$C_{15}H_{28}$.		

* ACETYLENE. Whenever a substance containing carbon and hydrogen undergoes incomplete combustion, this substance is formed. Certain metals form very peculiar compounds with acetylene, thus, CUPRO-ACETYL OXIDE, $(C_2Cu_2H)_2O$, is a red substance, obtained by passing acetylene into an ammoniacal solution of cuprous chloride, and a white powder of ARGENTO-ACETYL OXIDE, $(C_2Ag_2H)_2O$, results if the same gas be passed into an ammoniacal solution of a silver salt. These oxides are exceedingly explosive, and when heated with hydrochloric acid give off acetylene.

ALLYLENE, C_3H_4, is produced by acting with potash upon propylene dichloride.

The other substances in the series are strongly smelling liquids, and combine with two or four atoms of bromine.

TETRAVALENT ALCOHOLS.

The only one known is ERYTHRITE, $C_4H_6(HO)_4$, or $C_4H_{10}O_4$. This is a white solid substance, found in some fungi and lichens.

When erythrite is acted upon by hydriodic acid (HI), secondary butyl iodide results. Thus—

$$C_4H_{10}O_4 + 7HI = 6I + 4H_2O + C_4H_9I.$$

Iodine, water, and secondary butyl iodide are formed.

PENTAVALENT ALCOHOLS.

Only two are known, viz.: $C_6H_5(HO)_5$, or $C_6H_{10}O_5$, PINITE, occurring in hard sweet nodules, found in the sap of the Californian pine, and QUERCITE, in hard gritty crystals, obtained from acorns.

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* Part I.

HEXAVALENT ALCOHOLS.

Mannite, $C_6H_8(HO)_6$, or $C_6H_{14}O_6$, is the best-defined member of this series. It is the alcohol of an hexavalent radical, C_6H_8, and is a sugar-like substance contained in manna, an exudation from many species of ash.

Mannite is considered to possess hexatomic characters for the following reasons.

(1) When acted upon by nitric acid it forms a compound termed **Nitro-Mannite,** or mannite in which six atoms of hydrogen are replaced by NO_2. Thus—

$$\overset{vi}{C_6H_8},6(NO_2),O_6.$$

This last substance is to be regarded, not as a substitution product, but as the nitrate of a hexatomic radical corresponding to ethyl nitrate.

(2) (*a*) Hydriodic acid acts upon mannite in a similar manner as upon glycerine and erythrite, forming the monatomic iodide of the same number of carbon atoms. Thus—

$$C_6H_{14}O_6 + 11HI = 6H_2O + 10I + C_6H_{13}I.$$

Mannite and hydriodic acid yield water, iodine, and isohexyl iodide.

(*b*) Similarly the six hydrogen atoms may be replaced by six atoms of stearyl, $C_{18}H_{35}O$ (the radical of stearic acid). Thus—

$$\overset{vi}{C_6H_8},6(C_{18}H_{35}O),O_6 = \text{Mannite Hexastearate.}$$

Those substances which are obtained from glycerine, erythrite and mannite, and have the composition of the iodides of the monatomic radicals, are *not identical,* but *Isomeric,* with these iodides; they may be regarded as compounds of hydriodic acid with the olefine.

These bodies, when acted upon by water and oxide of silver, give rise to a hydrate resembling the monatomic alcohols in composition, but differing from them in its chemical relations and boiling point; these so-called Iso-Alcohols readily yield the olefines from which they are derived; by oxidation they form an acetone, hydrogen being removed, and they may be obtained by the action of hydrogen upon the acetone. Thus—

$$C_3H_6O + 2H = C_3H_8O_2.$$

Acetone and hydrogen form isopropyl alcohol.

SACCHARINE BODIES.

The term Carbo-Hydrates is often applied to these substances, since, in addition to carbon, they contain oxygen and hydrogen in the proportions to form water. They are divided into three classes.

1. SUCROSES (Sugars Proper).	2. GLUCOSES (Grape Sugars).	3. AMYLOSES (Starch and Woody Fibre).
$C_{12}H_{22}O_{11}(C_{12}11H_2O)$.	$C_6H_{12}O_6(C_66H_2O)$.	$C_6H_{10}O_5(C_65H_2O)$.
Sucrose + (Cane Sugar)	Dextrose + (Grape Sugar)	Starch +
		Glycogene +
Lactose + (Milk Sugar)	Levulose – (Fruit Sugar)	
		Dextrine +
		Inuline –
Melitose +		
Melezitose +	Galactose –	Gums
		Cellulose
Mycose +		Tunicine

All these bodies exert a peculiar influence upon polarised light. Those marked + have the power of turning the plane of polarisation to the right hand; those marked – turn the same plane to the left.

SUCROSES. $C_{12}H_{22}O_{11}$.

SUCROSE, or CANE SUGAR, is found in the juice of certain plants, especially the sugar-cane, mallow, and beetroot, and in smaller amount in honey and various fruits, mixed with levulose and dextrose. The sugar-cane contains about 18 per cent. of this sugar, which is prepared by crushing out the juice by passing the cane between rollers. The juice is immediately heated to about 60°C., a small amount of milk of lime being added to throw down any albuminous matter by which quick fermentation may be induced. The juice is then allowed to boil, the surface-scum is removed, and the remaining clear liquid is boiled to a certain consistence in copper pans; it is then filtered through linen bags and evaporated to a syrup, from which, when cooled, crystals of *Moist* or *Brown* Sugar are deposited. The mother liquor is a second time evaporated, and deposits more crystals on cooling. *Molasses* or *Treacle* is the name given to the uncrystallisable, dark-coloured sugar.

The process of *Refining* the sugar is principally performed in this country. The raw sugar is dissolved, boiled with lime and filtered. Decoloration is obtained by allowing the filtered liquid to flow through a bed of animal charcoal, and the filtrate is evaporated to the point of crystallisation.

Loaf Sugar is obtained by crystallising the concentrated syrup in moulds.

Cane Sugar is soluble in one-third of its weight in cold, and rather more of hot water; but it is nearly insoluble in ether and alcohol. Its specific gravity is 1·606. It melts at 160°C. to a colourless liquid, which, on cooling, solidifies to a transparent mass, *Barley-Sugar*, and, after standing, becomes opaque and crystalline. After exposure to a stronger heat, water is given off, and *Caramel*, a dark-coloured mass, remains behind.

Nitric acid converts cane-sugar into saccharic or oxalic acid, in proportion to the heat used and the strength of the acid; and by strong sulphuric acid it is reduced to a black mass after evolving sulphurous anhydride (SO_2).

The *Noble Metals* are easily reduced from their solutions on warming with solution of sucrose; but cupric salts are only slowly reduced in alkaline solutions of sucrose.

With some metallic oxides cane-sugar forms definite compounds, viz.: with lime, $CaOC_{12}H_{22}O_{11}$ (Sugar of Lime); and with lead, $Pb_2C_{12}H_{18}O_{11}$ (Sugar of Lead).

LACTOSE, or MILK SUGAR, is only found in the milk of mammalia. It dissolves in six parts of cold and two parts of boiling water; is not so sweet as sucrose, and feels *gritty* to the mouth. Lactose is converted by dilute acids in galactose, a peculiar variety of glucose, and in the presence of cheese sets up the lactic fermentation. An alkaline solution of copper is reduced by lactose in the cold, cuprous oxide (Cu_2O) being thrown down. By the oxidation of lactose, saccharic, mucic, tartaric and oxalic acids are yielded.

GLUCOSES. $C_6H_{12}O_6$.

DEXTROSE, or GRAPE SUGAR, is found in manna and honey, and many kinds of fruits, mixed with levulose. It is a normal constituent of the blood, and is present in small quantities in healthy urine, and is excreted by the urine in considerable amount in the disease called Glycosuria, or Diabetes Mellitus.

Dextrose may be obtained by boiling starch with dilute sulphuric acid, then adding chalk, and evaporating the liquid to a syrup, when the sugar crystallises. It is soluble in its own weight of water, and is readily soluble in dilute alcohol, but is not nearly so sweet as sucrose. Red cuprous oxide (Cu_2O) is speedily precipitated by dextrose from alkaline cupric solutions on boiling.

FERMENTATION.

This name is given to a peculiar class of decompositions, which differ from ordinary chemical actions.

Many organic bodies are capable of undergoing fermentation in the presence of certain complicated substances termed ferments, giving rise to products differing according to the nature of the fermented body and of the ferment.

This process depends upon the presence and growth of certain LIVING ORGANISMS forming the ferment. Most ferments are vegetable growths of a low kind, but that of the butyric appears to be animal. This cannot live in contact with free oxygen, but flourishes in an atmosphere of hydrogen.

The circumstances necessary for the growth of the ferment are:

Proper food, especially the ammoniacal salts and alkaline phosphates. These are contained in the albuminous matter generally present in the liquid about to be fermented.

A temperature from 20°C to 40°C, since at much higher or lower temperatures the vitality of the ferment is destroyed.

SPONTANEOUS FERMENTATION (no apparent ferment) takes place in wine, beer, milk and urine, these fluids becoming sour.

TRUE FERMENTATION. The sporules or seeds of living bodies always float in the air, and these, dropping into the liquid, propagate themselves, and during the act of growing evolve the products of fermentation.

Circumstances destructive or preventive of fermentation:

If the liquid be left in contact only with air which has been passed through a red-hot platinum tube, thus destroying the sporules.

If the air be simply filtered by passing it through cotton-wool, and the sporules thus prevented from coming into the liquid, these fermentable liquids may be preserved for any length of time without undergoing the slightest change.

THE PRINCIPAL FORMS OF FERMENTATION are five in number, viz.:

1. The ALCOHOLIC, producing chiefly Alcohol, C_2H_6O, and Carbonic Anhydride, CO_2.
2. The ACETOUS, producing chiefly Acetic Acid, $C_2H_4O_2$.
3. ,, LACTIC ,, ,, Lactic Acid, $C_3H_6O_3$.
4. ,, BUTYRIC ,, ,, Butyric Acid, $C_4H_8O_2$.
5. ,, MUCOUS ,, ,, Gum and Mannite, $C_6H_{14}O_6$.

This substance is also known *by the*
and may be obtained by heating starch
change is much more speedily effected
tle hydrochloric or nitric acid. Dex-
extrose, is formed when malt extract
insoluble in alcohol, but very soluble
iled with dilute acids is converted into
viates the polarised ray strongly to the

in the roots of many plants. When
it yields levulose. It is an interme-
n starch and gums.
ural exudation from many species of
iefly of Arabic acid, $C_{12}H_{20}O_{10}$, united
sium.
L STARCH, is an insoluble powder; it
glucose, and is formed in the placenta

la for this substance is $C_6H_{10}O_5$, or
numbers. It is widely spread over
d consists of a white powder, which is
f various sizes, and having a definite
These granules are not soluble in cold
, but if heated with water to 70°C. or
reak up, yielding a thick mass termed
oiling this mass with more water, the
such a fine state of division that they
er, and when the boiling is continued
ution becomes clear, and the starch
ution a white amorphous powder of
vn down by alcohol. Heat of 160°C.
xtrine.
s the formation with free iodine of a
the iodide of amiden), the colour of
00°C., and reappears on cooling. This
d by dextrine or the other starch

soluble azotised material of malt) acts
and dextrose are produced, and still
the dextrine into dextrose. Thus—

$$_2O = 2(C_6H_{10}O_5) + C_6H_{12}O_6.$$

er yield dextrine and dextrose.

Diluted sulphuric acts upon starch in a similar manner to diastase. Starch is dissolved by cold, strong sulphuric acid, with the formation of a compound acid. It is also dissolved by nitric acid, and if water be added to the solution, a white substance is thrown down. This is termed XYLOIDINE, and is a substitution product or starch in which NO_2 replaces one atom of hydrogen, viz. : $C_{12}H_{19}(NO_2)O_{10}$.

CELLULOSE, $C_6H_{10}O_5$, is the colourless material of the woody fibre of young plants. It is obtained pure by boiling out the impurities from linen fibre and cotton by means of an alkali, ether, alcohol, etc.

Cellulose is a white substance which dissolves in an ammoniacal solution of cupric oxide, but is insoluble in water, ether, or alcohol. Strong sulphuric acid converts cellulose either into a soluble substance like dextrine, or into an insoluble substance, giving a blue colour with iodine.

By dipping sheets of paper into strong sulphuric acid, a substance termed *Parchment Paper* is obtained.

GUN COTTON. When cotton-wool, in small portions at a time, is thrown into a mixture of equal volumes of strong nitric and sulphuric acids, no apparent change occurs; but after drying it is found to be exceedingly inflammable:

A substitution product is here formed termed TRINITRO-CELLULOSE, or cellulose in which NO_2 replaces three atoms of hydrogen, viz. : $C_6H_7(NO_2)_3O_5$. Nitric oxide is given off and cellulose is again formed upon the addition of ferrous chloride to this substance.

The use of gun-cotton as a substitute for gunpowder has been proposed for the following reasons :

*(1) The explosive force of gun-cotton is weight for weight greater than that of gunpowder.

(2) The products of combustion of gun-cotton, being chiefly carbon dioxide and nitrogen, are not so apt to foul the gun.

(3) When moistened it becomes inexplosive, and only requires drying to render it again explosive.

The general adoption of this substance is doubtful, upon the following considerations :

(1) The liability to explode on percussion ;

(2) The possibility of its spontaneous decomposition when kept for a length of time.

COLLODION is formed by dissolving gun-cotton, or certain forms of this substance, in a mixture of ether and alcohol. It is much employed in photography, in order to form a thin coating on the glass to receive the silver salts.

* Roscoe.

THE GLUCOSIDES.

The glucosides may be considered as compound ethers of glucose. They occur in many plants, and on decomposition give rise to a glucose, together with other substances. The chief of these substances are the following:

Amygdalin, Salicin, and Tannin.

AMYGDALIN, $C_{20}H_{27}NO_{11} + 3H_2O$, is found in bitter almonds, from which it is prepared by dissolving out with alcohol, and finally precipitating the amygdalin with ether. It forms white soluble crystals.

By the action of water (H_2O) upon the amygdalin and the albuminous substance termed *Synaptase* or *Emulsine*, contained in the bruised bitter almond, a species of fermentation is set up in which hydride of benzol (C_7H_6O), hydrocyanic acid (HCN), and glucose ($C_6H_{12}O_6$) are formed. Thus—

$$C_{20}H_{27}NO_{11} + 2H_2O = C_7H_6O + HCN + 2C_6H_{12}O_6.$$

SALICIN, $C_{13}H_{18}O_7$, is found in the pith of the *Poplar* and *Willow*, and also in *Castoreum*, a substance contained in the preputial follicles of the beaver. It crystallises in white brilliant needles. It is insoluble in ether, but soluble in water and alcohol, the solution having a strong bitter taste. Certain ferments decompose salicin as follows:

$$C_{13}H_{18}O_7 + H_2O = C_7H_8O_2 + C_6H_{12}O_6.$$

Saligenin and glucose are formed.

TANNIN, or TANNIC ACID, $C_{27}H_{22}O_{17}$, is widely diffused in certain parts of plants. It forms an insoluble substance with gelatin, and yields a blueish-black colour (ink) with the persalts of iron. The largest quantities of tannic acid are found in the gall-nuts (excrescences upon the *Quercus Infectoria*, or Dyer's oak, formed by the punctures and deposited ova of an insect, the *Diplolepis Gallæ Tinctoriæ*). The nuts are powdered, the acid being subsequently extracted by ether and water. When so prepared, tannin is an uncrystallisable mass, which is insoluble in pure ether, but is dissolved by water and by alcohol. When tannin is exposed to the air or treated with diluted acid, the following result takes place, viz.:

$$C_{27}H_{22}O_{17} + 4H_2O = C_6H_{12}O_6 + 3C_7H_6O_5.$$

Glucose and gallic acid are formed.

By heating tannin to 215°C. PYROGALLIC ACID is formed.

MYRONIC ACID, $C_{10}H_{19}NS_2O_{10}$. This acid exists in the seed of the *Black Mustard* as myronate of potassium, which is decomposed by an albuminous ferment contained in the mustard seed into allyl-sulphocyanate (the oil of mustard), glucose, and potassium hydric sulphate. Thus—

$$KC_{10}H_{18}NS_2O_{10} = C_3H_5,CN,S + C_6H_{12}O_6 + KHSO_4.$$

THE AROMATIC COMPOUNDS.

In these compounds a relatively less amount of hydrogen is contained than in those already described. They all contain at least six atoms of carbon, and the more complicated compounds of the series break up into those which contain six atoms. All the aromatic bodies appear to contain a group of six carbon atoms, in which, by the union of carbon with carbon, eighteen of the combining powers are taken up, six remaining free for saturation.

The simplest illustration of this series is Benzol, C_6H_6, and from this substance (by substitution of one or more atoms of hydrogen by more or less complicated molecules) numerous other substances are derived.

Four hydrocarbons homologous with benzol are known, differing by CH_2. These are, in reality, benzol in which the radical CH_3 (methyl) replaces one, two, or three atoms of hydrogen. Thus—

(1) Benzol	... C_6H_6.
(2) Benzol-Methyl, or Toluol ...	... $C_6H_5(CH_3)$ or C_7H_8.
(3) Benzol-Di-Methyl, or Xylol	... $C_6H_4 2(CH_3)$ or C_8H_{10}.
(4) Benzol-Tri-Methyl, or Cumol	... $C_6H_3 3(CH_3)$ or C_9H_{12}.

In each of these methylated benzols one or more atoms of hydrogen may be replaced by—

(1) Chlorine, yielding chlorine substitution products.

(2) By the monad radical NO_2, yielding nitro substitution products.

(3) By the monad radical NH_2, yielding amido compounds.

(4) By the monad radical HO, yielding alcohol-like bodies termed Phenols, together with a series of true alcohols, the isomers of the Phenols.

The following are some of the derivatives of Benzol and Benzol-Methyl, or Toluol, viz.:

Benzol	... C_6H_6.
Mono-Chlor-Benzol ...	... C_6H_5Cl.
Nitro-Benzol	... $C_6H_5(NO_2)$.
Aniline, or Amido-Benzol	... $C_6H_5(NH_2)$.
Phenol, or Carbolic Acid	... $C_6H_5(HO)$.
Toluol	... $C_6H_5(CH_3) = C_7H_8$.
Mono-Chlor-Toluol ...	... $C_6H_4Cl(CH_3) = C_7H_7Cl$.
Nitro-Toluol	... $C_6H_4(NO_2)(CH_3) = C_7H_7NO_2$.
Toluidine, or Amido-Toluol...	$C_6H_4(NH_2)(CH_3) = C_7H_9N$.
Cressol	... $C_6H_4(HO)(CH_3) = C_7H_8O$.

The **Benzyl Series** consists of certain bodies which are isomers of the toluol compounds, and in which the substitution occurs with the hydrogen of the methyl.

Toluol	... $C_6H_5(CH_3)$, or C_7H_8.
Benzyl-Chloride ...	... $C_6H_5(CH_2Cl)$, or C_7H_7Cl.
Benzylamine	... $C_6H_5(CH_2)H_2N$, or C_7H_7,H_2N.
Benzyl Alcohol ...	... $C_6H_5(CH_2)HO$, or C_7H_7,HO.

Benzyl Alcohol, by oxidation, yields an aldehyde, viz., **Oil of Bitter Almonds**, C_7H_6O, and an acid, **Benzoic Acid**, $C_7H_6O_2$; these are derived from benzyl alcohol in exactly the same manner as ethylic aldehyde and acetic acid from ethyl alcohol.

A similar double series of isomeric derivatives are afforded by the di- and tri- methyl benzols; and one or more atoms of hydrogen in benzol may be replaced by the radicals of all the higher alcohols, viz., ethyl, propyl, butyl, amyl, etc.

Ethyl Benzol, $(C_2H_5)C_6H_5$, is isomeric, but not identical with xylol or di-methyl benzol, $(CH_3)_2C_6H_4$.

Benzol, C_6H_6, is a colourless liquid, which refracts light strongly, and is found in the light oils resulting from the destructive distillation of coal; it may be artificially prepared by distilling together benzoic acid and slaked lime. Chlorine acts upon benzol with the formation of several chlorides.

Nitro-Benzol, $C_6H_5(NO_2)$, is a substitution product, in which the radical NO_2 replaces one of the hydrogen atoms of benzol. It is prepared by acting upon benzol with nitric acid.

Di-Nitro-Benzol, $C_6H_42(NO_2)$, is also known.

Aniline, or **Amido-Benzol**, $C_6H_5(NH_2)$, is one of the products of the destructive distillation of coal, and is obtained by the action of reducing agents upon nitro-benzol. Here the radical NH_2 replaces the radical NO_2. Thus—

$$C_6H_5(NO_2) + 6H = 2H_2O + C_6H_5(NH_2).$$

Nitro-benzol and hydrogen yield water and aniline.

The reduction is generally effected by mixing iron filings with acetic acid (hydrogen being generated). Aniline can also be obtained by acting upon isatine ($C_8H_5NO_2$) with potash (KHO). Thus—

$$C_8H_5NO_2 + 4KHO = 2H + 2K_2CO_3 + C_6H_7N.$$

Hydrogen, carbonate of potash and aniline are produced.

Aniline is a peculiar smelling, colourless liquid. It dissolves in ether and alcohol, but is nearly insoluble in water. It forms definite salts with acids, but does not render red litmus blue. The so-called aniline colours are much employed in silk and woollen dyeing and in calico printing.

By adding an aqueous solution of an alkaline hypochlorite to an aqueous solution of aniline a beautiful red colour results, and by this means the faintest trace of aniline may be detected. When aniline sulphate is added to bichromate of potash, an important substance is formed termed Mauve, in which a complicated base termed Mauveine ($C_{27}H_{24}N_4$) is contained. The same colour is produced by heating aniline with a double chloride of copper and sodium.

The derivatives of aniline are numerous. Thus—

Ethyl Aniline is $(C_2H_5)C_6H_5NH$.

Di-Amido-Benzol is $C_6H_42(NH_2)$.

The term Phenylamine, $C_6H_5H_2N$, has also been applied to aniline, but it is more proper to consider it an amido substitution product, since it cannot be prepared like an amine.

Phenol, or Carbolic Acid, $C_6H_5(HO)$, is a white crystalline solid body, found in heavy coal oils. It forms a phenate when dissolved in alkalies, but possesses no acid reaction. It is a powerful antiseptic, and is much used as a disinfectant.

Monochlor-Benzol, C_6H_5Cl, results when phenol is acted upon by pentachloride of phosphorus, or when chlorine acts directly upon benzol.

Picric Acid, or Tri-Nitro Phenol, $C_6H_3(NO_2)_3O$, is a yellow crystalline substance, very soluble in water, and is formed when nitric acid acts upon phenol, one, two, or three atoms of the hydrogen being replaced by NO_2. It may be obtained when nitric acid acts on many other substances, as the skin, for instance. In the arts it is employed as a dye for silk and wool.

TOLUIC OR BENZOLIC SERIES.

Toluol, or Methyl Benzol, CH_3,C_6H_5, occurs in coal-oils, but may be formed by distilling toluic acid with excess of lime. Oxidising agents convert toluol into benzoic acid $(C_7H_6O_2)$. Thus—

$$CH_3,C_6H_5 + 3O = H_2O + C_7H_6O_2.$$

Nitro-Toluol, $C_7H_7(NO_2)$, is formed when nitric acid acts upon toluol.

Toluidine, or Amido-Toluol, CH_3,C_6H_5,NH, is a solid substance, analogous to aniline, and is a necessary ingredient in the making of the violet and red aniline dyes. It is obtained by the action of reducing agents upon nitro-toluol.

Cressol, C_7H_7HO, is contained in crude carbolic acid. It is a crystallisable solid, and is homologous with phenol.

Rosaniline, $C_{20}H_{19}N_3$, is itself a colourless substance, but the beautiful red colour Magenta is formed by its compounds. It cannot be prepared from pure aniline, since toluidine must be present. Its formation may be shown as follows :

$$C_6H_7N + 2C_7H_9N + 3O = 3H_2O + C_{20}H_{19}N_3.$$

Aniline, toluidine, and oxygen yield water and rosaniline.

Leucaniline, $C_{20}H_{21}N_3$, is a substance which forms colourless salts, and is prepared by the action of nascent hydrogen upon rosaniline.

An Aniline Blue may be obtained by replacing three hydrogen atoms in rosaniline by Phenyl, C_6H_5.

An Aniline Violet, by the substitution of three atoms of methyl, ethyl, or any other alcohol radical.

Of the Aniline Greens, the most important are the "Aldehyde Green" and "Iodine Green."

Benzyl Alcohol, C_7H_7HO, is an oily, colourless liquid, which is formed when nascent hydrogen, or alcoholic potash, acts upon benzoic aldehyde, or oil of bitter almonds. It is converted by oxidising agents first into benzoic aldehyde, C_7H_6O, and finally into benzoic acid, $C_7H_6O_2$.

Benzoic Aldehyde, C_7H_6O, may be considered as Toluol, C_6H_5,CH_3, in which one atom of oxygen replaces two atoms of hydrogen ; thus—C_6H_5CHO. The vapour of bitter almond oil, when passed through a red-hot tube, is decomposed into carbonic oxide and benzol.

Benzoic Anhydride, or Benzoic Benzoate, $(C_7H_5O)_2O$, is a solid substance, soluble in ether and alcohol. It is formed by the action of benzoyl chloride (C_7H_5OCl) upon benzoate of potassium ($KC_7H_5O_2$). Thus—

$$KC_7H_5O_2 + C_7H_5OCl = KCl + (C_7H_5O)_2O.$$

Chloride of potassium and benzoic anhydride are formed.

Several mixed anhydrides exist, among them

Acetyl Benzoate, $C_2H_3O,C_7H_5O_2$.

Benzoic Acid, $C_7H_6O_2$, is found in many resins, but chiefly in benzoin. It is one of the constituents of the urine of the cow, but occurs in the urine of man and other animals after putrefaction. By heating benzoin, benzoic acid sublimes in white pearly plates. Most of the salts formed by benzoic acid are soluble ; but by adding ferric chloride to benzoate of sodium an insoluble red precipitate of ferric benzoate is thrown down.

Benzoyl Chloride, C_7H_5OCl, may be regarded as methyl benzol in which the two atoms of hydrogen in methyl are replaced by oxygen and the third atom by chlorine.

Benzoic Peroxide, $(C_7H_5O)_2O_2$, is obtained as a crystalline substance by acting upon benzoyl chloride (C_7H_5OCl) with barium peroxide (BaO_2). Thus—

$$2C_7H_5OCl + BaO_2 = BaCl_2 + (C_7H_5O)_2O_2.$$

Chloride of barium and benzoic peroxide are formed.

Benzylamine, C_7H_7,H_2N, is prepared as a colourless liquid by acting upon benzyl chloride with ammonia. It is the isomer of toluidine, and is a true amine, from which corresponding secondary and tertiary amines take origin.

Hippuric Acid, $C_9H_9NO_3$, is found in the urine of the horse and herbivorous animals. It is in reality **Glycocine**, $C_2H_3(NH_2)O_2$, in which the radical C_7H_5O of benzoic acid replaces one atom of hydrogen. It may therefore be written thus—C_2H_2,C_7H_5O,NH_2,O_2. By its passage through the animal body benzoic acid is converted into hippuric acid.

THE SALICYLIC GROUP.

In this group the dyad radicals C_7H_6, or C_7H_4O, are contained.

Salicyl Aldehyde, $C_7H_6O_2$, is the chief constituent of the volatile essential oil of the flowers of *Spiræa Ulmaria* (the meadow sweet). It may be formed by the oxidation of—

Saligenin, $C_7H_8O_4$. This is the alcohol of the series, and is derived from a bitter principle of *Willow Bark* (salicin). The following substances are evidently closely related:

$$\left.\begin{matrix} C_6H_4,HO,CH_2 \\ H \end{matrix}\right\} O; \qquad C_6H_4,HO,CH_3; \qquad \left.\begin{matrix} C_6H_5,CH_2 \\ H \end{matrix}\right\} O.$$

Saligenin. Cressol. Benzyl Alcohol.

Salicylic Acid, $C_7H_6O_3$, is formed by the oxidation of salicin, or salicyl aldehyde, and is found in the oil of the *Spiræa*. It may be obtained *synthetically* as the sodium salt by acting upon phenol (C_6H_5HO) with carbon dioxide (CO_2) and sodium (Na). Thus—

$$NaC_6H_5O + CO_2 = NaC_7H_5O_3.$$

Sodium Phenylate. Sodium Salicylate.

Carbon dioxide and phenol are again formed by the action of heat upon salicylic acid. This acid also occurs in the *Gaultheria Procumbens* (the oil of winter green) as the salicylate of methyl, $CH_3C_7H_5O_3$.

Gallic Acid, $C_7H_6O_5$, is obtained from tannin. It may be considered as salicylic acid in which two atoms of hydroxyl (HO) replace two atoms of hydrogen. It may also be obtained by acting with caustic potash (KHO) upon di-bromo-salicylic acid ($C_7H_4Br_2O_3$). Thus—

$$C_7H_4Br_2O_3 + 2KHO = 2KBr + C_7H_6O_5.$$

Bromide of potassium and gallic acid are formed.

Pyrogallic Acid, or **Benzol-Trihydroxyl**, $C_6H_3(HO)_3$, is formed, together with carbon dioxide, by heating gallic acid.

Indigo is the blue colouring matter of several species of *Indigofera*. By macerating the leaves in water oxidation takes place, and a yellow solution is formed, which, after exposure to air, precipitates a dark-blue powder (indigo); this is evaporated to dryness and cut into small cakes, and is then known as Commercial Indigo.

Indigotine, $C_{16}H_{10}N_2O_2$, is the pure colouring matter of the above substance, and is obtained in crystals by sublimation from the commercial indigo.

Indigo is insoluble in water, cold ether or alcohol, but is dissolved by strong sulphuric acid with the formation of a deep-blue solution. By exposing indigo to the action of alkalies or of reducing agents, hydrogen is absorbed, and a soluble colourless substance results, called **White Indigo**, $C_{16}H_{12}N_2O_2$.

This property is of great importance in indigo dyeing.

By heating indigo with caustic potash, salicylic acid is formed.

Isatine, $C_8H_5NO_2$, may be obtained in large yellow crystals by carefully oxidising indigo; when acted upon by potash, the following is the result—

$$C_8H_5NO_2 + 4KHO = 2H + 2K_2CO_3 + C_6H_7N.$$

Hydrogen, carbonate of potash and aniline are formed.

Indol, C_8H_7N, is a crystalline substance, and stands at the head of the indigo series. It is obtained by acting upon indigo first with tin and hydrochloric acid, and afterwards with zinc powder and water.

THE CINNAMYL GROUP.

Cinnamol, or **Styrol**, C_8H_8, is a powerfully refracting colourless liquid which is found in liquid *Storax*, and may be formed by heating acetylene to a high temperature.

Cinnamyl Alcohol, C_9H_9HO, is obtained by boiling styracin with alkalies; it crystallises in silky needles, having a sweet taste and a hyacinth smell.

Styracin is a cinnamate of cinnamyl, $C_9H_9,C_9H_7O_2$, which is contained in *Storax* and *Balsam of Peru.*

Cinnamic Aldehyde, C_9H_8O, is a colourless, cinnamon-smelling oil, and is the chief constituent of the essential oil of cinnamon.

Cinnamic Acid, $C_9H_8O_2$, is also found in *Storax* and *Peru Balsam*, but can be obtained by heating acetyl chloride (C_2H_3OCl) with oil of bitter almonds (C_6H_5CHO). Thus—

$$C_2H_3OCl + C_6H_5CHO = HCl + C_9H_8O_2.$$

Hydrochloric and cinnamic acids are formed.

By distilling this acid with caustic baryta, styrol (C_8H_8) is formed.

THE NAPHTHALIN GROUP.

Naphthalin, $C_{10}H_8$, occurs abundantly in the heavy coal-oils. It crystallises in white pearl-like plates, and is one of the products formed when the vapours of benzol alcohol or acetic acid are passed through a red-hot tube.

The eight hydrogen atoms of the above substance may be successively replaced by chlorine, and this gas will combine directly with naphthalin, forming $C_{10}H_8Cl_2$, the dichloride, and $C_{10}H_8Cl_4$, the tetrachloride.

When nitric acid acts upon naphthalin, three nitro substitution products result, viz.: $C_{10}H_7(NO_2)$, Mono-Nitro-Naphthalin; $C_{10}H_6(NO_2)_2$, Di-Nitro-Naphthalin; and $C_{10}H_5(NO_2)_3$, Tri-Nitro-Naphthalin; these are white crystalline solids.

Naphthylamine, or **Amido-Naphthalin**, $C_{10}H_7NH_2$, is obtained by the action of reducing agents upon mononitro-naphthalin; by its oxidation violet colours are produced.

Phthalic Acid, $C_8H_6O_4$, is formed by the further action of nitric acid on naphthalin.

Diazo-Naphthol Hydrochlorate, $C_{10}H_6N_2HCl$, results when a solution of potassium nitrite is added to a solution of hydrochlorate of naphthylamine.

Naphthol, $C_{10}H_8O$, is analogous to phenol, and is formed by heating the aqueous solution of the substance immediately preceding.

Naphthol yields nitro-substitution products, one of which, **Di-Nitro-Naphthol**, $C_{10}H_5(NO_2)_2HO$, yields the beautiful dye called **Naphthalin Yellow**.

THE ANTHRACENE GROUP.

Anthracene, $C_{14}H_{10}$, crystallises in silky, white needles, and is found in the least volatile portion of the coal-oils. It may also be obtained by heating benzyl chloride (C_7H_7Cl) with water at 190°C. in closed vessels. Thus—

$$4C_7H_7Cl + 2H_2O = 2H_2O + 4HCl + C_{14}H_{14} + C_{14}H_{10}.$$

Water, hydrochloric acid, dibenzol, and anthracene are formed.

OXYANTHRACENE, or **ANTHRAQUINONE**, $C_{14}H_8O_2$, together with nitro substitution products, is formed by the action of nitric acid on anthracene.

THE ALIZARINE GROUP.

ALIZARINE, $C_{14}H_8O_4$, is the colouring principle of madder, and is contained as a glucoside (**RUBIAN**) in the root. It may be prepared by heating strong sulphuric acid with anthraguinone, **DISULPHO-ANTHRAQUINIC ACID** ($C_{14}H_6O_2(HSO_3)_2$) being formed, which, by fusion with potash (KHO), is converted into sulphite of potash (K_2SO_3) and disulpho-anthraquinate of potash ($C_{14}H_6O_3 2(KSO_3)$); this last substance, when treated with hydrochloric acid, yields Alizarin.

Alizarin is precipitated as long red needles; it forms red insoluble compounds, called *Lakes*, with stannic oxide and alumina, and a black or purple substance with ferric oxide. Solutions of these oxides are termed, in calico printing, *Mordants*. Alizarin forms with a mordant an insoluble pink, purple, chocolate, or black, according to the character of the mordant.

PURPURINE, $C_{14}H_8O_5$, is another red colouring principle contained in the madder root.

CHRYSOPHANIC ACID is an isomer of alizarine. It occurs in rhubarb and goa powder, and is a derivative of anthracene.

TURPENTINES AND ISOMERS. $C_{10}H_{16}$.

The commercial oil of turpentine is obtained from many species of pine, and usually consists of a mixture of several isomeric modifications of turpentine. The common turpentine is found in the *Pinus Nigra*, *Abies*, and *Silvestris*, whilst the Venice turpentine is obtained from the *Larch*. Upon distillation with water in a retort, colophony, or rosin, is left behind, and an aromatic volatile liquid is given off.

TEREBENTHENE and **AUSTRA TEREBENTHENE** are natural varieties. The former is derived from the *Pinus Maritima*, and turns the plane of polarisation to the left hand. The latter is obtained from *Pinus Australis*, and turns the same plane to the right.

By oxidation of turpentine, resins are formed.

Among the isomers of turpentine are many *Essential Oils*, viz.: those of lemons, lavender, caraway, cloves, etc. These often contain other oxidised oils, the most important of which is—

LAUREL, or COMMON CAMPHOR, $C_{10}H_{16}O$. This is chiefly obtained from the *Laurus Camphora* of Japan and China.

THE CAMPHOR GROUP AND TURPENTINES.

This series apparently possesses a common group of ten carbon atoms, and from them a large number of isomers are derived. Many of these substances seem to be identical in their chemical relations, but their physical properties differ, and on this account they are termed *Physical Isomers.* The following hydrocarbons give origin to these substances.

$C_{10}H_{20}$, Diamylene ; $C_{10}H_{18}$, Camphene, or Menthene ;
$C_{10}H_{16}$, Terebene and its isomers ; $C_{10}H_{14}$, Cymol.

Oxidised products are yielded by the above substances, and these are termed Camphors, viz :

$C_{10}H_{14}O$, Carvol, or Thymol ; $C_{10}H_{16}O$, Laurel Camphor ;
$C_{10}H_{18}O$, Borneo Camphor ; $C_{10}H_{20}O$, Menthene Camphor.

Acids result from the further oxidation, viz. :

$C_{10}H_{16}$, Terebene ... ... yields with O_2 ; $C_{10}H_{16}O_2$, Camphinic Acid.
$C_{10}H_{16}O$, Laurel Camphor yields with O_3 ; $C_{10}H_{16}O_4$, Camphoric Acid.

Camphor is a crystalline white mass, usually described as a concrete volatile oil. Its solution in alcohol deflects the polarised ray to the right.

Upon heating camphor it is first converted into Borneo Camphor, $C_{10}H_{18}O$, and finally into Camphinic Acid, $C_{10}H_{16}O_2$, and Campholic Acid, $C_{10}H_{18}O$. Boiling nitric acid oxidises camphor to Camphoric Acid, $C_{10}H_{16}O_4$.

BALS AMAND RESINS. Colophony, or rosin, is prepared by distilling crude turpentine. The resins, as mastic, copal, and lac, are similar in composition, and are produced by the oxidation of the terebenes.

GUTTA PERCHA, INDIA-RUBBER, or CAOUTCHOUC. All these are compounds of carbon and hydrogen.

GUTTA-PERCHA is the hardened juice of one of the *Sapotaceæ* found in Singapore and Borneo. When pure, it is white, and soluble in ether.

Caoutchouc is the hardened juice of the tropical trees, *Siphonia Cahuchu, Ficus Elastica, and Jatropha Elastica.* It combines with sulphur in several proportions, with the formation of commercial vulcanised caoutchouc.

By strongly heating vulcanised caoutchouc with sulphur, *Vulcanite*, or *Ebonite*, a horny black mass, is formed.

NATURAL ORGANIC BASES, OR VEGETO-ALKALOIDS.

The exact constitution of these bodies is as yet unknown. They are believed to belong to the class of compound ammonias, and contain carbon, hydrogen, nitrogen and oxygen, but they have not, for the most part, been artificially prepared.

Some few are volatile and liquid, containing only nitrogen, carbon and hydrogen; but they all powerfully influence the ray of polarised light, some causing the plane to deviate to the left and some to the right. They combine with acids forming salts, and thus they resemble ammonia. For instance—

Ammonia Gas, NH_3 + Hydrochloric Acid, $HCl = NH_3HCl$,
or NH_4Cl = Hydrochlorate of Ammonia.

Morphia, $C_{17}H_{19}NO_3 + HCl = C_{17}H_{19}NO_3HCl$, or $C_{17}H_{20}NO_3Cl$
= Hydrochlorate of Morphia.

The alkaloids form, with perchloride of platinum, double crystallisable salts; they act violently upon the animal economy, some, as morphia and quinia, being very valuable medicines, and others, as nicotine, belladonna, and strychnia, being active poisons.

ALKALOIDS IN WHICH CARBON, HYDROGEN AND NITROGEN ARE CONTAINED.

Conia, $C_8H_{15}N$. This substance is found in the *Conium Maculatum*, or the spotted hemlock. It is a colourless liquid, with a strong alkaline reaction, and forms salts with acids. It acts as a narcotic poison, and, under certain conditions, yields butyric acid by oxidation.

Nicotina, $C_{10}H_{14}N_2$, is the chief alkaloid of the *Nicotiana Tabacum*, or Tobacco, in which from 2 to 8 per cent. is contained. This substance is soluble in water, ether, and alcohol, and is one of the most deadly poisons known. It contains no hydrogen replaceable by an alcohol radical, and yields a salt corresponding to iodide of ammonium (NH_4I) when heated with iodide of ethyl (C_2H_5I):

Nicotina.	Nicotine-Ethyl-Iodide.
$(C_5\overset{\text{III}}{H}_7)_2N_2$;	$(C_5H_7)_2,(C_2H_5)_22NI$.

Piperidina, $C_5H_{11}N$. This alkaloid is prepared by the distillation with an alkali, of Piperin, $C_{17}H_{19}NO_3$, a base contained in

Piper Nigrum, the black pepper. It contains an atom of hydrogen, which is replaceable by an alcohol group, and thus its real formula is $\left.\begin{matrix}C_5H_{10}\\H\end{matrix}\right\}N$. It possesses a strong odour of pepper, and is a colourless fluid.

ALKALOIDS IN WHICH CARBON, HYDROGEN, OXYGEN AND NITROGEN ARE CONTAINED.

ALKALOIDS OF THE CINCHONAS. These are two in number, viz.: CINCHONINE and QUININE, each respectively yielding two isomeric modifications, viz.: Cinchonidine and Cinchonicine; Quinidine and Quinicine. QUINIC, or KINIC ACID is combined with these alkaloids.

CINCHONINE, $C_{20}H_{24}N_2O$. This substance is less soluble in alcohol than quinine, and is therefore separated by this fluid. Thirty parts of boiling alcohol are required to dissolve cinchonine, which consequently crystallises out, whilst the quinine remains in solution.

CINCHONIDINE is found with quinidine in the brown resinous mass which remains after cinchonine and quinine have been extracted. It turns the plane of polarisation to the left.

CINCHONICINE may be prepared by heating sulphate of cinchonine to 120°C. or 130°C. By this substance the plane of polarisation is turned feebly to the right.

QUININE, or QUINIA, $C_{20}H_{24}N_2O_2$. This alkaloid requires 350 parts of cold water and two parts of alcohol for its solution. The solution has a bitter taste, and turns the polarised ray to the left. Quinia, when heated with iodide of ethyl, forms a salt of an ammonium compound, and therefore apparently possesses no replaceable hydrogen.

Tests for Quinia—

(1) If ferrocyanide of potassium be thrown into a solution of quinine in chlorine water, *a deep-red colour* appears.

(2) Should excess of ammonia be added to the same solution in chlorine water an *emerald-green colour* is produced.

(3) The sulphate of this alkaloid also communicates a *fluorescence* to its solutions.

QUINICINE may be obtained by acting upon quinine by heat. It is a substance of semi-solid, resinous consistence, and bitter to the taste; it turns the polarised ray feebly to the right.

QUINIDINE somewhat resembles quinine in its qualities as a febrifuge; but by it the plane of polarisation is strongly turned to the right.

The manner in which the above alkaloids act upon the plane of polarisation is the following :

Cinchonine deflects the plane strongly to the right.
Cinchonidine „ „ strongly to the left.
Cinchonicine „ „ feebly to the right.
Quinine „ „ strongly to the left.
Quinicine „ „ feebly to the right.
Quinidine „ „ strongly to the right.

THE ALKALOIDS OF OPIUM. These are contained in the *Papaver Somniferum.* The following six are the most important :

1. Morphia.
2. Codeia.
3. Narcotina.
4. Narceia.
5. Papaverina.
6. Thebaia.

In addition to the above, a neutral crystallisable substance exists, termed—

MECONINE, $C_{10}H_{10}O_4$; also an acid (MECONIC ACID, $C_7H_4O_7$), with which the alkaloids are mainly united, together with vegetable matter, etc. The most powerful of the alkaloids is Thebaia, then Papaverina, Codeia, and Morphia.

MORPHIA, $C_{17}H_{19}NO_3 + H_2O$. This substance dissolves in 1000 parts of cold and 400 of boiling water. It is insoluble in ether, but is readily dissolved by hot alcohol. This alkaloid would seem to contain no replaceable hydrogen, since, when treated with ethyl iodide, an iodide of ammonium is produced.

Tests for Morphia and its Salts—

1. *Nitric Acid* applied to dry morphia, or to a very strong solution of the alkaloid, turns it an *orange* colour.

2. If a drop of a carefully-neutralised solution of *perchloride of iron* be added to the alkaloid, a *deep blue* is produced, changing to *green* on the addition of an excess of the test liquid.

3. If a trace of *iodic acid* be added to a solution of morphia the liquid becomes *brown.* When a drop of this solution is allowed to fall on a piece of starch paper, the blue iodide of starch will immediately form.

4. *Sulpho-Molybdic Acid* gives a *reddish-purple,* changing to *green,* and ultimately to *blue.*

CODEIA, $C_{18}H_{21}NO_3 + H_2O$, is contained in the mother liquor after the crystallisation of morphia.

NARCOTINA, $C_{22}H_{23}NO_7$, dissolves in 128 parts of boiling alcohol and nineteen of boiling ether. When opium is treated with water, this substance remains insoluble, and is obtained by the addition of hydrochloric acid to the "marc," or insoluble portion of the opium. The basic powers of narcotina are very feeble, and it is not strictly speaking an alkaloid, since it is destitute of alkaline reaction.

PAPAVERINA, $C_{20}H_{21}NO_4$, yields a *deep-blue colour* with strong sulphuric acid.

THEBAIA, or PARAMORPHIA, $C_{19}H_{21}NO_3$, and NARCEIA, $C_{23}H_{29}NO_9$, are contained in very small quantities.

THE ALKALOIDS OF STRYCHNOS. These are two in number, viz.: STRYCHNIA and BRUCIA, and exist in the *Strychnos Ignatia* and *Strychnos Nux Vomica.* They are combined with IGASURIC, or STRYCHNIC ACID.

STRYCHNIA, $C_{21}H_{22}N_2O_2$, is a violent poison, acting especially upon the motor tract of the spinal cord, producing tetanic convulsions, etc.

The *Tests for Strychnia* are the following—

1. The intense bitterness a small quantity communicates to a large quantity of water.

2. When injected in solution into the lymph-pouch of a frog, the animal is seized with violent tetanic spasms upon the slightest touch. Dr. Harley asserts that on injecting the $\frac{1}{18000}$ of a grain of strychnia into the lungs of a small frog, tetanic convulsions occurred in 9½ minutes, and death in two hours.

3. The *colour* test. The strychnia is placed on a white plate and touched with a drop of strong sulphuric acid. No change of colour occurs, but a sulphate of strychnia is formed. A very small quantity of finely-powdered black oxide of manganese, or peroxide of lead, or bichromate of potash is now added to the solution, and an *iridescent* play of colours is exhibited, the order of the tints being as follows:

Blue, passing into purple, then violet, then red, the mixture becoming finally colourless, or nearly so.

BRUCIA, $C_{23}H_{26}N_2O_4 + 4H_2O$, is less poisonous than the preceding substance; and by some authors it is said to be inert; it yields a *bright scarlet colour* with strong nitric acid.

THEOBROMINE, $C_7H_8N_4O_2$, is an alkaloid found in *Theobroma Cacao*, or Cacao Butter. By replacing one atom of hydrogen in this substance by methyl, the following substance is obtained:

THEINE, CAFEINE, or METHYL THEOBROMINE, $C_8H_{10}N_4O_2 + H_2O$. This is the active principle of coffee and tea. It is found in *Guarana* (a variety of chocolate made from the fruit of

Paulinia Sorbilis), and in the leaves of the *Ilex Paraguayensis*, employed by the South Americans as a substitute for tea.

Tea	contains	about	2	per cent.	of Theine.
Coffee	,,	,,	0·8 to 1	,,	,,
Guarana	,,	,,	5	,,	,,
Paraguay Tea	,,	,,	1·2	,,	,,

THE ALBUMINOUS SUBSTANCES, ALBUMINOIDS, OR PROTEIDS.

Many of these substances are very complicated in their constitution. They form an essential part of the bodies of animals, and are found in certain parts of vegetables, especially in the seeds. They exist in a jelly-like, amorphous form, and do not crystallise. In addition to carbon, hydrogen, nitrogen, and oxygen, they all contain sulphur, and the majority phosphorus.

Albumen is contained in the serum, or liquid portion of the blood, and may be seen in its purest form in the white of egg, from which it may be obtained by the addition of acetic acid, and dilution with water, a white flocculent precipitate of albumen falling; upon drying, a transparent, yellow, gum-like mass is formed, which is insoluble in cold water, but dissolves in the presence of a trace of free alkali. The chief characteristic of albumen is its coagulability by heat, since at about 65°C. it becomes opaque and solid.

Fibrin exists in solution in the blood, but solidifies when the blood leaves the living body. It is obtained either by washing the thick part of the blood (the clot) until the red colour is destroyed, or by agitating fresh blood with twigs, when it appears as colourless filaments without taste, and insoluble in water.

The fibrin of blood differs from that of flesh, and that from venous blood is soluble in nitrate of potash, which is not the case with arterial fibrin.

Casein. This is a nitrogenous substance contained in cheese and milk. It is nearly allied to albumen and is coagulated by acids; it is insoluble in pure water, but dissolved by a dilute solution of an alkali.

When milk is boiled the casein is not coagulated, but an acid, or part of the internal coating of the stomach of the calf, termed *Rennet*, immediately separates out the butter and casein as *Curds*, leaving the lactose, or milk-sugar, and salts, in solution as *Whey*.

Glutin, the sticky, elastic substance combined with starch in wheaten flour, is really vegetable fibrin.

It is impossible to give any formulæ for the substances just described, but their percentage composition may be shown from the following :*

	Albumen.	Fibrin.	Casein.
Carbon	53·5	52·7	53·8
Hydrogen	7·0	6·9	7·2
Nitrogen	15·5	15·4	15·6
Oxygen	22·0	23·5	22·5
Sulphur	1·6	1·2	0·9
Phosphorus	0·4	0·3	0·0
	100·0	100·0	100·0

Gelatin is a nitrogenous substance prepared from the animal body. It is obtained by boiling certain tissues, and is known as isinglass, gelatin, and glue. Its composition is identical with that of the tissue employed in its preparation.

ANIMAL CHEMISTRY.

The Bones are chiefly composed of the tribasic phosphate of lime ($Ca_3P_2O_8$) together with a variety of gelatin.

Hydrochloric acid dissolves the phosphate, leaving the bone as a gelatinous, elastic mass. The friable and earthly matter alone remains after burning. The following is the composition of human bone, viz. :

†Animal matter, soluble by boiling	32·17
Vascular substances	1·13
Calcium phosphate, with a little calcium fluoride	53·04
Calcium carbonate	11·30
Magnesium phosphate	1·16
Soda and a little common salt	1·20
	100·00

The Blood, in health, has a specific gravity of 1·055, and, according to some authors, in 100 parts its average composition is the following :

Serum, or Liquor Sanguinis	Water	79·00	87·0
	Albumen	7·00	
	Salts	0·94	
	Fatty matters	0·06	
Crassamentum Coagulum, or Clot.	Fibrin	0·30	13·0
	Corpuscles	12·70	
			100·0

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* Roscoe.

† Berzelius.

The following is the composition of healthy human blood as a whole, according to Lecanu:

	(1)	(2)
Water	780·15	785·58
Fibrin	2·10	3·57
Albumen	65·09	69·41
Colouring matter	133·00	119·63
Crystallisable fat	2·43	4·30
Fluid fat...	1·31	2·27
Extractive matter of uncertain nature, soluble in both water and alcohol ...	1·79	1·92
Albumen in combination with soda ...	1·26	2·01
Sodium and potassium chlorides, carbonates, phosphates and sulphates...	8·37	7·30
Calcium and magnesium carbonates, phosphates of calcium, magnesium and iron; ferric oxide	2·10	1·42
Loss	2·40	2·59
	1000·00	1000·00

Through the blood animals receive the necessary supply of materials for their growth and for the repair of waste; and by this fluid they are also able to remove the worn out matters. The blood of the vertebrata is of a red colour, and its temperature is higher than that of the medium in which the animal exists.

In man it is 98°F. (36°·9C.), and in birds 109°F. (48°·8C.); and this temperature is remarkably constant under the most varying conditions of climate. The blood corpuscles are of two kinds, the red and the white, and they float in a colourless liquid. *The red corpuscles are flattened circular discs, on an average $\frac{1}{3200}$ of an inch in diameter, and having about one-fourth of that thickness. The broad faces of the discs are somewhat concave, and thus, when the corpuscle is viewed under the microscope by transmitted light, it appears clear in the middle and darker at the edges. When the discs roll over, thus presenting their edges, they look like rods. The red corpuscles consist of a semi-fluid substance termed globulin, reddened by the hæmatin, around which no cell-wall has been clearly made out. When exposed to oxygen gas they are made flatter, when to carbonic anhydride, they swell out.

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* Huxley.

The white, or colourless, corpuscles are larger than the red, their average diameter being $\frac{1}{2500}$ of an inch. Their form is extremely irregular.

The white corpuscles have a tendency to attach themselves to the microscopic slide, whilst the red corpuscles float about and tumble freely over one another.

The proportion in number of the white to the red corpuscles is as 1 to 400 or 500.

The blood corpuscles differ in shape in different animals, being round, in man and the carnivora, but elliptical in birds, lizards, frogs and fish.

The diameter of the blood discs in the frog is four times that in man.

The colouring matter of the blood is due to *hæmatin*, an uncrystallisable substance formed by the decomposition of *hæmoglobin*, in which the following elements are contained, viz., carbon, hydrogen, nitrogen, oxygen, sulphur and iron.

There is about 7 per cent. of iron in hæmatin, but this metal may be removed by sulphuric acid, and no apparent alteration of the red colouring is observed.

All warm-blooded animals possess two kinds of blood; the *Arterial* or *Red* blood contained in the arteries and left side of the heart, and the *Venous* or *Purple* blood contained in the veins and right side of the heart. By oxidation in the lungs the venous blood becomes arterial.

The gases oxygen, nitrogen, and carbonic anhydride are dissolved in the blood, the oxidation of the tissues being occasioned in the presence of the first-named.

ARTERIAL BLOOD (freshly oxidised from the lungs) contains in 100 volumes:

Nitrogen	14·5
Carbonic Anhydride ...	62·3
Oxygen	23·2
	100·0

VENOUS BLOOD (charged with the products of the combustion of the body):

Nitrogen	13·1
Carbonic Anhydride ...	71·6
Oxygen	15·3
	100·0

The colouring matter of the blood, or hæmoglobin, differs in its physical properties in different animals as follows :

*(*a*) In the facility with which it forms crystals, and in the form of the crystals.

(*b*) In its solubility ; the crystals from the blood of an ox are very readily soluble in water, while those from the blood of the raven are almost insoluble in that fluid.

Hæmoglobin exists in the blood in two different conditions of oxidation, which are designated by the names oxyhæmoglobin and reduced hæmoglobin. The latter contains the less quantity of oxygen, and exists in venous blood ; as the blood circulates in the lung it is separated from the air in the air-cells by a very thin membrane, through which the oxygen passes into the blood ; it enters into a peculiar loose chemical combination with the colouring matter to form oxyhæmoglobin.

Oxyhæmoglobin undergoes, in the capillary circulation, the opposite change to that which occurs in the pulmonary circulation ; the oxyhæmoglobin is decomposed, oxygen passes into the tissues, and reduced hæmoglobin returns to the venous system, by the lungs, to receive a fresh supply of oxygen. The colouring matter is therefore the carrier of oxygen from the air to the tissues.

When carbon monoxide (CO) acts upon oxyhæmoglobin, it drives out all the loosely-combined oxygen, forming with the reduced hæmoglobin a compound which is much more stable than oxyhæmoglobin, and from which the carbon monoxide cannot be again displaced by oxygen.

The SALIVA consists of a mixture of several fluids secreted by the glands of the mouth. It is generally alkaline, and contains an albuminous principle termed *Ptyalin,* which rapidly converts starchy matters into sugar. It also contains *Sulphocyanide Potassium,* which is readily detected by its giving a blood-red colour with the ferric salts.

The solid constituents of saliva are fixed salts, chiefly chlorides, with phosphate and carbonate of lime.

The PANCREATIC FLUID is strongly alkaline, and contains an albuminous principle similar to ptyalin, together with leucine, xanthine and inosite, and a small quantity of chlorides and phosphates. This fluid converts starch into sugar with more energy than the saliva, and at a temperature of 35°C. it changes fat into fatty acid and glycerin, and quickly dissolves boiled albumin and fibrin at the same temperature.

The GASTRIC JUICE is a colourless, transparent fluid, with an acid reaction. It contains *Lactic, Propionic, Butyric, Acetic* and *Hydrochloric Acids*, and a principle called *Pepsin*, by which the digestion and solution of the albuminous materials are chiefly performed.

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* R. A. Witthaus.

The Bile is a fluid secreted by the liver, and poured out into the duodenum. It consists essentially of a mixture of the sodium salts of two peculiar acids, viz., Glycocholic Acid ($C_{26}H_{43}NO_6$), and Taurocholic Acid ($C_{26}H_{45}NSO_7$), together with a body called Taurine ($C_2H_7NSO_3$), and bile pigments known as Bilirubin, or Cholepyrrhin, and Biliverdin.

The Urine is a fluid secreted by the kidneys from the arterial blood, and it is in this that a great portion of the waste nitrogenous parts of the body pass off as uric acid and urea.

The composition of the urine in 1000 parts is, roughly, the following:

Water		950
Urea		25
Uric Acid		1
Fixed Salts	Chloride of Sodium	14
	Salts of Ammonia	
	Alkaline Phosphates	
	Alkaline Sulphates	
	Phosphates of Lime and Magnesia	
Organic Matters	Extractive	10
	Creatine and Creatinine	
	Colouring Matter	
		1000

The quantity of urine normally excreted by an adult in 24 hours is about 20 to 40 ounces; but it may exceed this average by the ingestion of large quantities of fluids, as in beer drinkers; in winter; and in individuals of sedentary habits. It is pathologically increased in diabetes and hysteria. It may be below the average in summer, and generally under all conditions by which the amount of perspiration and pulmonary exhalation is increased. It is pathologically diminished in acute febrile diseases, and in all diseases attended by dropsical effusions or watery discharges. The colour of the urine varies physiologically as follows:

The greater the quantity of urine voided, the lighter, as a rule, is the colour.

Urine voided in the morning is darker than that at other times. The use of certain drugs imparts a peculiar colour to the urine: rhubarb gives *bright yellow;* logwood, *reddish;* senna, *brownish;* santonin, *orange-red* or *golden-yellow*.

Pathologically the urine is rendered pale in anæmia, and in those conditions which produce an increase in the quantity, and it is similarly heightened in colour under those conditions in which the quantity of water eliminated by the kidneys is diminished, while the elimination of solids remains normal, or is increased.

The presence of bile may render the urine brown, or even black.

The specific gravity of healthy urine varies from 1015 to 102[illegible], but after copious drinking upon an empty stomach the specific gravity may fall as low as 1001, and again it may rise to 103[illegible] after a full meal.

The urine of females is usually slightly lower in specific gravity than in males, except during pregnancy, at which period the specific gravity is normally about 1030.

The urine of herbivorous animals is alkaline in reaction, whilst in the carnivorous it is strongly acid.

In man its reaction is faintly acid, since his food is a blending of animal with vegetable substances.

The colour of the urine is probably due to at least two colouring matters, *Urobilin* and *Indican*.

Milk varies in composition in different animals, but each variety possesses all the materials requisite for forming the body of the young animal: it therefore contains fats (butter) and lactose, or milk-sugar, casein (nearly identical in composition with flesh), together with inorganic salts, especially alkaline chlorides and lime phosphates, which are necessary to the formation of bone.

The specific gravity of milk varies from 1·03 to 1·04, and its average composition in different animals is the following:

	Woman.	Cow.	Goat.	Ass.	Bitch.
Water	[illegible]	87·4	82·0	90·5	66·3
Butter	2·7	4·0	4·5	1·4	14·8
Milk-Sugar and Soluble Salts ...	[illegible]	5·0	[illegible]	6·4	2·9
Casein and [illegible]	[illegible]	3·6	[illegible]	[illegible]	16·0

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by acting upon ethylene oxide (C_2H_4O) with a strong solution of trimethylamine (($(CH_3)_3N$)). Thus—

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The respiratory process consists in the aëration of the blood which circulates through the lungs, or some analogous apparatus, through the agency of the oxygen of the air. The blood is separated from the air by an extensive surface of extremely fine membrane; and through this, by solution and diffusion, the exchange of gases takes place. By this means also the blood is relieved of the products of combustion.

From 22 to 43 cubic inches of air are thrown out from the human lungs at each ordinary respiration.

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Animals live upon *Organised* substances, giving off carbonic anhydride and other oxidised products, but taking up oxygen; their function is therefore *Oxidation.*

The bulk of the plant is merely increased by food, whereas, when an animal has attained full growth, the food serves to repair tissue waste. The sun supplies to the plant the activity requisite for its food organisation, whilst the oxidation of its own body supplies to the animal the activity necessary for its existence.

ANIMAL HEAT AND RESPIRATION.

The respiratory process consists in the aëration of the blood which circulates through the lungs, or some analogous apparatus, through the agency of the oxygen of the air. The blood is separated from the air by an extensive surface of extremely fine membrane; and through this, by solution and diffusion, the exchange of gases takes place. By this means also the blood is relieved of the products of combustion.

From 22 to 43 cubic inches of air are thrown out from the human lungs at each ordinary respiration.

It is stated that as much as 100 and as little as 3 cubic inches have been expired. By a forced effort, from 50 to 60 cubic inches are ordinarily expelled, and possibly from 100 to 300 cubic inches may be expired after a full inspiration; but even then the lungs are not emptied of air, and the residual amount has been estimated at from 40 to 260 cubic inches. From 77 to 170 cubic inches may be expired after an ordinary expiration; and by the deepest sigh, after an ordinary inspiration, from 119 to 200 more cubic inches may be drawn into the lungs.

The number of respirations varies from 14 to 16 per minute, but the number, even in health, varies from 9 to 20. Expired air contains from 3 to 6 per cent. of carbonic anhydride, but the quantity of the carbonic anhydride exhaled varies con-

Pathologically the urine is rendered pale in anæmia, and in those conditions which produce an increase in the quantity, and it is similarly heightened in colour under those conditions in which the quantity of water eliminated by the kidneys is diminished, while the elimination of solids remains normal, or is increased.

The presence of bile may render the urine brown, or even black.

The specific gravity of healthy urine varies from 1015 to 1025; but after copious drinking upon an empty stomach the specific gravity may fall as low as 1001, and again it may rise to 1030 after a full meal.

The urine of females is usually slightly lower in specific gravity than in males, except during pregnancy, at which period the specific gravity is normally about 1030.

The urine of herbivorous animals is alkaline in reaction, whilst in the carnivorous it is strongly acid.

In man its reaction is faintly acid, since his food is a blending of animal with vegetable substances.

The colour of the urine is probably due to at least two colouring matters, *Urobilin* and *Indican*.

MILK varies in composition in different animals, but each variety possesses all the materials requisite for forming the body of the young animal: it therefore contains fats (butter) and lactose, or milk-sugar, casein (nearly identical in composition with flesh), together with inorganic salts, especially alkaline chlorides and lime phosphates, which are necessary to the formation of bone.

The specific gravity of milk varies from 1·03 to 1·04, and its average composition in different animals is the following:

	Woman.	Cow.	Goat.	Ass.	Bitch.
Water	[illegible]	[illegible]	82·0	90·5	66·3
Butter ...	[illegible]	[illegible]	4·5	1·4	14·8
Milk-Sugar	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Salt	[illegible]	[illegible]	4·5	6·4	2·9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16·0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]